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ORIGINAL ARTICLES.

I.—Further Notes on the Stratigraphy and Fauna of the Trimmingham Chalk.

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(WITH 13 TEXT-FIGURES.)

(*Concluded from the March Number, p.* 131.)

BEFORE proceeding to the description of new species it may perhaps be well to make a few remarks on the classification of the Cretaceous Polyzoa and in particular of the Cheilostomata, the suborder which embraces all the species I propose to describe.

The main features of D'Orbigny's classification of the Cyclostomata have been generally accepted, but his classification of the Cheilostomata has suffered very severely at the hands of subsequent authors both in principle and in detail. It was based very largely on two principles, one the generic importance of habits of growth, and the other the generic importance of variations in the number and position of the dwarfed avicularian appendages which he called 'pores spéciaux.' The latter principle has been entirely discarded by recent authors, and with undoubted justice, as it involves the assumption of the perfect regularity of the most irregular feature of the Cheilostomatous cell. The application of the other principle and the importance attributed to it have been gradually more and more restricted, until we have reached a stage where it is still generally admitted to hold good in the case of the Lunulitidæ and Hippothoidæ, but on the strength of the behaviour of certain recent and Tertiary species has been denied even specific importance in the other Cheilostomatous families. It is time that a protest was entered against this rigid application of conclusions drawn from Tertiary and recent forms to the classification of Cretaceous forms. It is unfortunately the case that D'Orbigny, by an oversight in applying his principle in detail, laid it unnecessarily open to attack. It must be obvious that even if the principle be fully accepted, the separation which D'Orbigny made between the free and encrusting unilamellate species, e.g., *Semieschara* and *Cellepora*, *Semiflustrella* and *Reptoflustrella*, must be unsound. It is quite impossible to say that any of the free unilamellate forms found in the Chalk *grew* free. Seaweeds

and other perishable bodies must have been fairly plentiful in the Chalk sea—in the zone of *B. quadrata* we find great numbers of free small *Serpulæ* (*ampullacea* and *granulata*) whose bases show clearly that they grew attached to some long slender body, no doubt a seaweed—and any specimens which had grown attached to such perishable bodies would now be indistinguishable from those which had never been encrusting. These two forms of growth are, in fact, not unfrequently shared by Cretaceous species, e.g., *Homalostega respertilio* and *Cribrilina Gregoryi*, though the majority of encrusting forms are practically never found free, and some free forms, e.g. *Semieschara Canui* (*post*), are never found encrusting. If D'Orbigny's unilamellate genera, which are separated only by this point of growth, be merged, we have left a number of genera based on habits of growth which constitute for the Cretaceous forms convenient and often natural groups which do not seriously overlap. No doubt they are artificial, but that is not yet a destructive criticism of any classification of the Polyzoa.

But though it may well remain a matter of individual opinion whether habits of growth are of any value in the definition of genera, I do not think that any field student of the Cretaceous Cheilostomata would deny them great value in the definition of species. It is very rare in the English Chalk for any species to occur in more than one habit of growth (treating the free and encrusting unilamellate forms of growth as identical). A better test could hardly be offered than the two very similar Onychocellæ figured respectively by D'Orbigny as *Cellepora Parisiensis* and by Beissel as *Eschara galeata* (the latter species is the one commonly identified as *E. Lamarcki*, but which corresponds only to Beissel's figure of *E. galeata*). *E. galeata* is a bilamellate form and the most abundant Cheilostome at all horizons above the zone of *M. cor-testudinarium*. The specimens which have passed through my hands must run well into tens of thousands, yet I have only one encrusting specimen and no mature free unilamellate specimen, notwithstanding that it commonly grows from an unilamellate base. *Cellepora Parisiensis*, on the other hand, is one of the commonest encrusting species, and I must have seen thousands of specimens, yet I have no bilamellate specimen (and only one free unilamellate specimen). Stronger testimony to the fidelity of these species at any rate to a certain habit of growth can hardly be possible, and nearly all species of Cretaceous Cheilostomata show equal or nearly equal fidelity. Here, then, we have a point of considerable importance, in which the rigid application to Cretaceous forms of canons of classification derived from the study of Tertiary and recent forms is very undesirable.

Another such point is to be found in the prevailing tendency to unite Cretaceous, Tertiary, and recent specimens in one species. This involves the general assumption that polyps which produce skeletons which cannot be distinguished *must* be identical in organisation. We can admit the absolute propriety of this assumption in the case of specimens more or less contemporaneous and yet

be free to doubt whether it must necessarily hold good in the case of specimens of widely differing age. The Polyzoa are a particularly good group in which to test this alleged persistence of Cretaceous forms into recent seas, for the complexity of their skeletons, at any rate in the Cheilostomata, makes it possible to define an enormous number of species, in fact all but the most primitive, with clearness and certainty in a way unattainable in other groups. Now it is not strongly marked species that are identified both in recent seas and the Chalk, but primitive forms such as *Stomatopora granulata* and *Membranipora reticulum*. I am not inclined to admit that the presence in the Chalk of *Membraniporæ* whose skeleton cannot be distinguished by any absolute character from that of the recent *M. reticulum* is conclusive or even presumptive evidence that polyps identical with those of the recent *M. reticulum* lived in the Chalk sea. It is not necessarily the case that because we habitually assume that a simple polyp did not have a specialised skeleton we are entitled to assume the converse that a specialised polyp did have a specialised skeleton, or in other words that a simple cell like that of *M. reticulum* could not be sufficient for the requirements of two or more differently organised polyps. There is nothing that I can see to warrant this assumption, and until it can be supported by stronger evidence it seems more prudent to continue to recognise the great physical break between the Cretaceous and Tertiary epochs as a justification for refusing to admit the identity of primitive Cretaceous forms with recent species.

From the foregoing it will be gathered that I desire to see it recognised as a principle that in dealing with the Cretaceous Polyzoa we are not bound by the Tertiary and recent forms, and any strict assimilation would be *a priori* injudicious, for it must be remembered that the recent Cheilostomata with hard skeletons, the only ones which can be compared with the Cretaceous Cheilostomata, may fairly be considered to form a group in which the general lines of development have long been settled, a middle-aged group. They are, from the geological standpoint, absolutely contemporaneous, but represent almost every possible variety of surrounding conditions. The Cretaceous Cheilostomata, on the other hand, represent the vigorous youth of the group when all sorts of experiments in development were taking place, not only those which resulted in the formation of stable families and genera which still exist, but also those which produced such unstable and shortlived families as the Melicertitidæ. They represent a long period, but on the whole only one set of conditions. Under these circumstances it is only to be expected that rules which apply to one fauna will not always apply satisfactorily to the other. Differences which in one case were of genuine specific importance might well in the other indicate merely variations of a single species under the influence of distance in space and variety of surroundings, and capable of being proved to be such by a chain of intermediate forms. The importance of taking such considerations into account is exemplified by the history of Hagenow's species *Onychocella (Cellepora) Koninckiana*. Hagenow gave two

figures of this species, and at first sight it would seem impossible that they should belong to the same species. Gregory accordingly gave to the second figure the specific name of *Hagenowi*. This involved the attribution to Hagenow of a careless blunder, but would have been justifiable, as far as the creation of species from published figures only can be justifiable, if Hagenow's specimens had come from the settled conditions of ordinary Chalk. But they came from the unsettled shallow-water conditions of the Maestricht Beds, where unprogressive variation, as well as the progressive variation which we call evolution, would be particularly likely to occur in the Cheilostomata, and I have little doubt that Hagenow united his figures in one species for the reason that I reunite them, namely, that he had seen specimens responding accurately in different parts to both figures. The species is evidently a variation which did not prove advantageous and so did not lead to further developments, and to which as a species from Maestricht we need not attach any importance, but which, if it were to appear in recent seas, would be a bombshell indeed.

The recent genera *Mucronella* and *Cribrilina* do not give satisfactory results when applied to the Cretaceous Polyzoa. In the first place, the accepted definition of *Cribrilina* excludes species with radiating or transverse furrows which are not punctured. There does not, however, seem to be good ground for treating the presence or absence of pores in the furrows (a point often very obscure in fossil forms) as necessarily generic, and I propose for convenience to treat the definition of the genus as extended accordingly. In the second place, the two genera cover an enormous number of Cretaceous species, and a study of these indicates that many of them possess characters which would, if their front walls were not furrowed, place them in entirely different genera and even families. Can such forms be logically retained in a single genus? Certainly *Cribrilina* and *Membraniporella* are not for the Cretaceous forms genera in the same sense that, say, *Mucronella* and *Porina* are, but rather agglomerations of the early stages of development of other families and genera, while the family and generic peculiarities were coming into existence, and after they had come into existence, but while the development of a fully calcified front wall was still incomplete. If the two genera were dismembered a large number of species could be successfully grouped with other families; indeed, I think additions out of the Cribrilinidæ would be made to nearly all the important groups except the Celleporidæ, Porinidæ, and Hippothoidæ, and it is interesting to note that Jullien puts the two latter groups in a separate suborder. Even if the Cribrilinidæ are not dealt with in this way the Cretaceous forms suggest that they are the product of two totally distinct lines of development from the primitive Membraniporidan cell. One of these lines is the commonly recognised one, the arching over and fusion in the middle line of marginal spines. But this will not satisfactorily account for the very large number of species in which the front wall is attached to the side of the side walls and does not rest on their surface.

Here the front wall must have arisen by symmetrical calcification of the membranous covering, starting no doubt from points along its junction with the side walls and proceeding inwards. There would therefore, on this hypothesis, be a morphological distinction of the greatest importance in the Cribrilinidæ (and through them in the majority of the Cheilostomata) between cells with a distinct rim and those without a distinct rim, a distinction which would make it impossible to retain the family Cribrilinidæ. It is distinctly favourable to this hypothesis that Marsson has on other grounds given great prominence to the question of rim or no rim in classifying the Cheilostomata. The Cretaceous forms also suggest a third line of development of the calcified front wall through such forms as *Membranipora Trimminghamensis* (*post*). The cell in these forms is clearly an ordinary Membraniporidan cell tilted forwards, and by the squaring of the lower part of the aperture and pressing downwards of the straight lower lip thus formed, we pass by easy stages represented by the Cretaceous forms of *Pyripora* to a *Micropora* practically indistinguishable from one developed through Cribrilinid forms, but with a front wall morphologically quite distinct in its origin from those developed through Cribrilinid forms.

DESCRIPTION OF SPECIES.

A. *Trimmingham Species.*

MEMBRANIPORA GRIFFITHI,[1] sp. nov. (Fig. 1.)

Colony adherent, normally growing equally in all directions with almost the regularity of a *Lunulites*, and possessing a common crust out of which the cells stand sharply. Cell nearly circular, with a sharp-edged, narrow, smooth wall. The mature cells almost invariably have both an ovicell and an avicularium. Ovicell immediately above the cell, about half the width of the zoœcium,

FIG. 1.

and of the usual semi-globose shape. In a large number there is a triangular incision in the rounded end, apparently giving double access to the interior, and the sides of the ovicell are extended along the side wall of the avicularium as far as the crossbar. Avicularium sharply triangular, placed immediately above the ovicell. It is spanned close to its base by a very slender bar, which is often

[1] Dedicated to Mr. C. Griffith, of Winchester, a friend of long standing, who first introduced me to the study of geology.

preserved. Large vicarious specialised cells, possibly vibracularia, occur scantily but regularly. They are long, rather narrow, and constricted towards the lower end. The aperture is situate at the lower end, and is round below and pointed above. The lower two-thirds of it are enclosed by the cell-wall, and the upper one-third by a depressed front wall, which occupies the rest of the area.

MEMBRANIPORA TRIMMINGHAMENSIS, sp. nov. (Fig. 2.)

Colony adherent, growing as a rule in one direction only. Cell elongated and pear-shaped, with an oval aperture occupying with its marginal wall (which has its edges bevelled off) rather more than half the cell, the lower part forming an external area and tapering away. On the marginal wall is a single row of denticles. At the upper end the marginal wall is exceedingly thin, which is easily

FIG. 2.

seen, owing to the free edge of the ovicell being concave. Ovicell globose, narrower than in the preceding species, but similarly placed at the head of the aperture. Avicularium placed above the ovicell, oval with an oval aperture, divided into two lobes (the upper being slightly the larger) by two lateral denticles, which were joined by a slender bar, which is generally destroyed. This species can almost be constructed from the preceding one by rounding and smoothing all sharp angles and corners.

MEMBRANIPORA BRITANNICA, sp. nov. (Fig. 3.)

Colony adherent. Cell subcircular to oval, the marginal wall chiefly a common wall. On the foot of practically every cell is placed either the ovicell or the avicularium of the cell below. The ovicell is of the semi-globose type, but wide, flattened, and steep-sided, so as to appear almost rectangular. Its free edge

FIG. 3.

a. Group of cells showing ovicells and perfectly preserved avicularia.
b. Cell with usual type of avicularium.

coincides exactly with the outline of the cell-wall beneath. Avicularium mandibular and placed transversely with the point of the mandible indifferently to the right or left. It is generally stumpy (*b*), but in well-preserved specimens the point is long and

slender and projects over the adjacent cell (*a*). The point being raised much higher than the rounded end, the aperture is in an inclined plane facing the cell adjacent to the base of the avicularium. It is an almost invariable rule that every cell (except the very early ones) has either an ovicell *or* an avicularium. The species is very characteristic of the Trimmingham Chalk, but is recognisable in the zone of *M. cor-anguinum*, though rare below the zone of *B. mucronata*.

Semieschara Mundesleiensis, sp. nov. (Fig. 4.)

Colony always adherent. Cell large and subpyriform, with the external area of the pyriform type occupying usually about one-third of the cell, but only tapering very slightly as a rule. Where the marginal wall divides the internal and external area it is very faint. The aperture is very large and occupies nearly the whole of the space within the marginal wall, and is slightly heart-shaped, its lower margin being indented by a blunt denticle projecting from the internal area. The internal area is usually very insignificant, but is

Fig. 4.

very variable in extent, and may absorb almost the whole external area. It slopes forwards and downwards. The ovicells are not at all prominent, and are little more than swellings of the foot of the succeeding cell, but have a very remarkable thickened broad rim to the aperture. Avicularia rare and very irregular in occurrence. They are narrow elongated membraniporine cells, with a slight area at the foot sloping gently towards the aperture, which is slightly constricted rather above the middle. The size of the aperture makes the species easily recognisable.

Semieschara Canui,[1] sp. nov. (Fig. 5.)

Colony always free, but unilamellate. Cells relatively broad, aperture placed in the upper third, small, trifoliate, upper lobe semi-

Fig. 5.

circular, other lobes narrow and exactly alike. No ovicell observed. Avicularium an elongated cell, slightly constricted rather above the

[1] Named in honour of my friend M. F. Canu, the French authority on Polyzoa.

middle at a point on a line with the upper edge of the aperture, which is small and transversely oval, with a strongly denticulated lower lip.

ESCHARA ROWEI, sp. nov. (Fig. 6.)

Colony free, bilamellate, growing in expanding fronds, which are very fragile. Cell long and narrow, aperture occupying quite half the cell, heel-shaped, and elongated, with sides constricted close to the lower lip, and a strongly projecting lower lip. No ovicell. Avicularium an elongated cell with pointed ends, broad in the middle,

FIG. 6.

tapering more rapidly below than above. Aperture rather below the middle, appearing under a low power as a transverse oblong with rounded corners, and a distinct pore above and a faint pore below (*a*). Under higher powers the structure shown in (*b*) is revealed. This structure is rarely preserved, the specimens generally presenting it in varying degrees of ruin.

CRIBRILINA SHERBORNI, sp. nov. (Fig. 7.)

Colony always adherent. Cell widely oval, apparently based on a primitive form (*a*), with an elongated heel-shaped aperture in a plane at a slight angle to the horizontal, a front wall rising from all sides to a central circular platform in which are cut a series of radiating furrows, two long lateral slits in the front wall commencing between the aperture and the margin and running outwards close to the margin, and a globose ovicell at the top of the cell some distance above the aperture. The first stage of development appears to be that the lower lip of the aperture rises slightly, and the rest of the

FIG. 7.

margin of the aperture rises considerably to form with the upper edge of the aperture of the ovicell an oval secondary aperture (*b*). Next there are developed over the lateral slits lateral avicularia, set on legs so as to allow free access of water to the slits (*c*). These avicularia are very faintly mandibular, with the point of the mandible on the inner side, but the least attrition makes them circular. At the same time the sides and base of the secondary aperture are further raised, and the sides are produced up the sloping surface of the ovicell to meet at the central crown. In the final stage (*d*) the

avicularia develop very decided beaks, connected by a thin, almost horizontal plate into a barrier right across the cell which overhangs and entirely conceals the primary aperture, while even the area between the primary aperture and the ovicell is now so deep set as to be visible only in special lights. It is the rule for every cell to attain this stage, but the fragility of the plate between the avicularia produces many variations in the shape of the secondary aperture when the specimen is handled at all roughly. *Cellepora pinguis*, Hag., appears to be a relation.

Cribrilina Dibleyi, sp. nov. (Fig. 8.)

Colony always adherent. Cell elongated. Aperture heel-shaped, surrounded by a flat raised margin, the lower lip being triangular, with the apex directed down the front wall. The upper lip bears four or five hollow denticles (when there are five the fifth is a small one between the two at the head of the cell). Ovicell large and globose, with faint radial markings, and covers the two (or three) upper denticles. Front wall marked by about 17 lines of fine

Fig. 8.

pores, increasing slightly in size towards the margin. These lines do not (except the topmost pair) meet in the middle, but leave an imperforate bar down the centre. Nearly every cell has one avicularium, many have two. They are either mandibular and slender, with thin marginal walls connected by a slender rod near the base, or broadly oval. The latter are probably decayed or worn specimens.

Cribrilina Jukes-Brownei, sp. nov. (Fig. 9.)

Colony always adherent, generally growing in narrow ribbons. Cell based on a primitive form like *Reptescharella inæqualis*, D'Orb., but with a decided rim. It has a long globose ovicell, up the front of which two slender ridges run diagonally from each corner of the aperture, meeting in an angle at nearly the highest point of the ovicell. The lower lip of the aperture is produced forwards and upwards into a broad band in three sections. The lowest of these is bluntly triangular, with the apex pointing downwards. At the sides of the cell it rises gently to the second section, which is, however, strongly arched in the middle, and so leaves there an opening between it and the first section. The third section is at a higher level still, more or less flattened and buttressed, apparently not against the side walls but against two lateral tubes (presumably

avicularian), which rest on the side walls and open just beside the aperture. In the centre this third section rests on the second section, and its lower edge having a deep sinus an inlier of the second section is exposed. At the sides the third section rises considerably above the second section, and so there is a well-marked opening left. The upper edge of this third section carries two very minute and slender beak-shaped avicularia lying transversely with their beaks directed inwards. These constitute the apparent lower lip of the aperture, and according as they do not quite meet, just meet, or rather more than meet, in the middle line, the apparent lip has

Fig. 9.

a central sinus, is quite straight, or has a central denticle. This apparent lip is on the same vertical plane as the deep-set aperture of the ovicell, and entirely conceals the aperture of the cell, and leaves only a small space between itself and the sloping surface of the ovicell. Below the transverse band is seen the normal front wall with five pairs of radiating furrows, and a single unpaired one in the middle line at the foot. The ovicell and transverse band are practically always present, and the species, which is quite small, is easily recognisable with a pocket magnifier, though the details are hardly discernible under the microscope.

Mucronella Batheri, sp. nov. (Fig. 10.)

Colony always adherent, small and very prominent, partly owing to the compactness of its surface and partly apparently to its being bilamellate. The cells of the lower lamella are wide, but very shallow, and some of them may generally be seen round the edge of the colony. They rarely exhibit more than the marginal wall, but occasionally one may be seen with a front wall consisting apparently of a number of irregular plates with a round pore in the centre. On

Fig. 10.

the foundation afforded by these cells is built a layer of cells of normal depth. Here the primitive cell is a simple lepralian cell with an oval aperture in a sloping plane. But as the cell matures the lower lip of the aperture is produced in the plane of the surface of the colony into a broad square mucro overhanging the greater part of the aperture and leaving only a very narrow space on either side of it and between it and the broad ovicell. The latter is nearly

always present, and is set on the base of the succeeding cell, and so deeply sunk that its rather flattened upper surface is practically flush with the general surface of the colony. This gives the colony its uniquely compact appearance. Every cell bears one or two avicularia, consisting of long slender tubes lying on the front wall with the wider and open end a short way below the mucro, and tapering away posteriorly and sinking gradually into the front wall. Cells which carry at the foot the ovicell of a preceding cell have two lateral avicularia; those which do not carry such an ovicell (e.g. the first of an intercalated series) have one median avicularium.

B. *Senonian Species.*

Semieschara Woodsi, sp. nov. (Fig. 11.)

Colony usually adherent, occasionally free and unilamellate. Cells hexagonal and arranged quincuncially. Aperture approximately oblong and transverse, the upper lip being sometimes rather shorter than the lower, and sometimes slightly convex. This upper lip slopes sharply inwards, and may therefore be overlooked unless the light is thrown from the *foot* of the cell. Ovicell very rare, merely a swelling of the foot of the succeeding cell. Avicularia fairly but

Fig. 11.

variably plentiful. They are separate cells, but not vicarious. They are more or less shuttle-shaped, with a small round aperture in the point of the shuttle. The species appears at least as low as the Marsupite zone, but attains its zenith in the base of the *B. mucronata* zone. It is probably lineally related to *Cellepora Michaudiana*, D'O., but easily distinguished by the shape of the apertures both of cell and avicularium.

Semieschara Pergensi, sp. nov. (Fig. 12.)

Colony adherent. Cells hexagonal, of varying dimensions, arranged more or less quincuncially with a very broad and ill-defined common wall. Front wall arched from side to side, and also sinking slightly

Fig. 12.

from the foot (where it is almost on a level with the top of the cell-wall) towards the aperture. The aperture is semicircular and large,

with rounded basal angles, and stretches from side wall to side wall, but its apparent breadth is restricted by a very slight infold of the inner edge of the side walls. The lower lip is almost straight, but the very slight curve is often accentuated by the arching of the front wall from side to side. The avicularium is an elongated cell with an oval aperture occupying two-thirds of the area, and touching the cell-walls at its widest, but separated from them above that point by a very slight deep-seated front wall, and below that point by a considerable front wall rising towards the foot of the cell to the plane of the top of the cell-wall. The species is very characteristic of the upper part of the zone of *B. quadrata*.

Cribrilina Gregoryi, sp. nov. (Fig. 13.)

Colony either adherent or free and unilamellate. Cells large, with walls on the whole common, though often showing signs of separation. Aperture large and semicircular, surrounded by a broad smooth border, which extends between the upper edge of the aperture and the foot of the next cell for a distance equal to or greater than the height of the aperture. From the upper part of this band two prominent denticles project out over the aperture. The front wall springs from slightly below the surface of the side walls, and is gently arched. It bears about seven rows of punctures, running straight across from side to side, the two punctures next the side walls being much larger than the others. There are usually two avicularia, always one, to each cell, closely associated with the

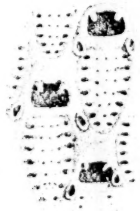


Fig. 13.

lower corners of the band round the aperture. They are small and mandibular, but except in well-preserved specimens from the zone of *B. quadrata*, where this species reaches its zenith, the mandible is poorly or not at all developed, and the avicularia present themselves as very small circular perforate denticles. No ovicell has yet been observed, though many thousands of specimens have been seen. The species most nearly resembles *Semieschariporà dentata*, D'Orb. (which is, however, near the *Membraniporellæ*), but is easily distinguished from that and all other species by the two imperforate denticles overhanging the aperture. It appears in the zone of *M. cor-testudinarium* (at Seaford), and becomes steadily more prevalent until in the upper part of the zone of *B. quadrata* it is the dominant form; above the base of the zone of *B. mucronata* it soon becomes comparatively rare.

II.—Sedgwick Museum Notes.

New Fossils from the Bokkeveld Beds, South Africa.

By F. R. Cowper Reed, M.A., F.G.S.

(PLATES XVI and XVII.)

A SMALL collection of fossils from the Bokkeveld Beds has recently been sent to me for identification by the South African Museum, and some of them have been generously presented to the Sedgwick Museum. Amongst this material it is interesting to find some genera not previously recorded from the Cape and some new species. The majority of the specimens are in the condition of internal casts, and hence present especial difficulties in their determination, so that in a few cases some uncertainty must remain as to the generic position of the fossils. However, I am able to record for the first time from these beds the occurrence of the well-known lamellibranchiate genus *Buchiola*, and of a shell which may be identified with *Nyassa arguta*, Hall, of the North American Devonian. The genus *Buchiola* occurs in argillaceous nodules from the Zwartberg Pass crowded with individuals of the species which I have named *B. subpalmata* and with a few examples of an undetermined species. No other associated fossils can be recognised in these nodules, but I am informed that an abundant fauna is found in the beds at this locality.

There are only single specimens in the collection of the species which I have determined as *Nuculites* cf. *Smithi*, *Sanguinolites* (?) *acer*, and *Nyassa arguta*, and only two of *Sanguinolites niger*. The fine large brachiopod which appears to be probably referable to the little-known Bolivian genus *Scaphiocœlia*, or may belong to a completely new generic type, is represented by eight specimens, all of which are sandstone casts with occasionally portions of the shell attached.

The genus *Ptychospira* is now for the first time identified in the Bokkeveld Beds.

The following is a list of the species in the collection :—

[1] *Tentaculites crotalinus*, Salter.
Buchiola subpalmata, sp. nov.
Buchiola sp. ind.
[1] *Nuculites* cf. *Smithi*, Clarke.
Sanguinolites niger, sp. nov.
S. (?) *acer*, sp. nov.
Nyassa arguta, Hall.
Scaphiocœlia (?) *africana*, sp. nov.
Rensselæria cf. *confluentina*, Fuchs.
[1] *Ptychospira variegata*, sp. nov.

The present author has previously published an account of the principal collection of brachiopods and molluscs from the Bokkeveld Beds in the Annals of the South African Museum, vol. iv, pts. 3 and 6 (1903–1904).

[1] These three species occur associated together on the same rock specimens from an unknown locality.

LAMELLIBRANCHIATA.

BUCHIOLA SUBPALMATA, sp. nov. (Pl. XVI, Figs. 1, 1*a*, 2.)

Diagnosis.—Shell subquadrate or subcircular, nearly equilateral and nearly as high as wide, more or less swollen; hinge-line straight, shorter than shell, cardinal angles obtusely rounded. Beaks subcentral, a little nearer anterior than posterior end, opposed, directed slightly forwards, strongly incurved. Valves more or less inflated, most so in middle, somewhat compressed near cardinal region on both sides of beaks. Surface marked with 11–13 raised, flattened, radiating ribs with sharp edges, elevated abruptly above the narrower intercostal grooves, which are rounded. The middle 5–7 ribs are stronger than the others, of subequal height and size, and curved slightly forwards; at the margin of the shell they are 1½–2 times wider than the separating grooves. The anterior 2–3 ribs are smaller, less elevated, and slightly concave on their surface, and are curved more upwards; the posterior 3–5 are likewise lower and much less conspicuous than the middle ones, and have their surface sometimes rather concave, and they are curved up slightly towards the hinge-line. Fine, inconspicuous, regular, closely set, concentric striæ cross the ribs and grooves, and are slightly arched on the former. (These are not distinctly shown in the figures.)

Dimensions:

Average length	... ...	5·5–6·0 mm.
,, height	... ...	5·25–5·5 ,,
,, thickness	... ...	3·50–4·25 ,,

Locality.—Zwartberg Pass.

Remarks.—The genus *Buchiola* has not been previously recorded from South Africa, and I have not found it mentioned amongst the Devonian fossils from South America, to which the fauna of the Bokkeveld Beds has been shown to bear a close resemblance in composition and species. It is, on the other hand, a characteristic European genus, represented, especially in the Rhenish Devonian, by many species which Beushausen[1] has described, and it occurs also in North America, where Hall applied the generic name *Glyptocardia* to it. The range of the genus extends from the Upper Silurian (Bohemia) to the upper horizons of the Devonian. In the Rhenish provinces it appears to be limited to the Middle and Upper Devonian.

The affinities of our South African form are undoubtedly with *B. palmata* (Goldfuss)[2] in the shape, number, and distribution of the ribs; but as regards the subequilateral form of the shell and its inflated character *B. ruppachensis*, Beush.,[3] resembles it more closely. *B. speciosa* (Hall),[4] from the Genesee Slate, is closely allied to, if not identical with, *B. palmata*, as Beushausen has observed.

[1] Beushausen, Lamell. rhein. Devon: Abh. kön. preuss. geol. Landesanst., N.F., xvii (1895), pp. 322–338, pls. xxxiv, xxxv.
[2] Ibid., p. 333, pl. xxxiv, figs. 3–5.
[3] Ibid., p. 324, pl. xxxiv, figs. 8*a–f*.
[4] Hall: Palæont. N.Y., vol. v, pt. 1 (1883), pl. lxv, figs. 6–8.

The South African form, however, appears sufficiently distinct from all the described species of *Buchiola* to warrant a separate specific designation, and the name *subpalmata* is accordingly proposed as indicating its nearest ally.

Buchiola sp. ind.

There is another species of *Buchiola* occurring in the nodules from the Zwartberg Pass, but I have only been able to discover impressions of portions of the exterior surface or imperfect internal casts. It is characterised by the ribs being very flat and scarcely elevated above the shallow grooves, and by both being of equal width. The ribs are broad and few in number, and bear arched striæ; but the material is too poor for further details. *B. angulifera*, Roemer,[1] appears to resemble it in the character of the ribs.

Locality.—Zwartberg Pass.

Nuculites cf. Smithi, Clarke.

One specimen of a shell belonging to the genus *Nuculites* occurs on the same slab of greyish micaceous clay as *Tentaculites crotalinus* and *Ptychospira variegata*, and comes from an unknown locality. It consists of a right valve (with the ends slightly broken) of an elongate species, having the clavicular ridge set unusually far forward in front of the beak, which is placed at about two-fifths the length of the shell from the anterior end. The general shape of the shell, position of the beak and clavicular ridge, more resemble *N. Smithi*, Clarke,[2] from the Devonian of Brazil, than the allied *N. africanus* (Salter)[3] from the Bokkeveld Beds; and it is also comparable with *N. elongatus* (Conrad) of the Hamilton Group of New York.

Dimensions:

Length	*ca.* 20 mm.
Height	*ca.* 12 ,,

Locality.—Unknown.

Nyassa arguta, Hall (?). (Pl. XVI, Figs. 3, 3*a*.)

One somewhat imperfect internal cast of a lamellibranch from the Zwartberg Pass shows the following characters:—Shell elongated, oval, slightly curved, widest in front, narrowing a little posteriorly, and obliquely truncated behind. Valves gibbous, especially in anterior portion, not compressed nor flattened behind. Beaks low, subterminal, very broad, obtuse, rounded; a strong curved umbonal ridge runs to postero-inferior angle of shell; and a broad, well-marked, but shallow depression, widening below, extends obliquely from beak in front of ridge to inferior margin, occupying nearly two-thirds the length of the shell. Hinge-line arched; inferior margin broadly and rather deeply sinuated; anterior end broadly

[1] Beushausen: op. cit., p. 337, pl. xxxv, figs. 18, 19.

[2] Clarke, Palæoz. Faunas of Para: Archiv Mus. Nac. Rio de Janeiro, vol. x (1899) (English edit.), p. 71, pl. viii, fig. 5.

[3] Sharpe: Trans. Geol. Soc., ser. II, vol. vii, p. 211, pl. xxvii, fig. 2 (? 4). Reed: Ann. S. Afr. Mus., vol. iv, pt. 6 (1904), p. 256.

rounded; posterior end narrowed, truncated above, somewhat pointed below. Cardinal margins of valves strongly thickened internally as far forward as anterior adductor scars, with traces of 3–4 small elongated pits in hinge-plate between and in front of beaks. Adductor scars deeply impressed, oval, obliquely placed close below beaks and on anterior lateral margin. Surface of shell marked with a few strong oblique concentric growth-ridges.

Dimensions:

Length	25 mm.
Height	15 ,,
Thickness	14 ,,

Locality.—Zwartberg Pass.

Remarks.—This shell appears to be identical with *Nyassa arguta*, Hall,[1] from the Hamilton Group of North America. It is only in the matter of the teeth (which probably are absent in our specimen owing to its condition of preservation) that any difference is noticeable. Beushausen[2] identifies Goldfuss' *Sanguinolaria dorsata* from the Upper Calceola Beds and the Stringocephalus Limestone with the American species. I am doubtful if Sharpe's *Sanguinolites* (?) *corrugatus*[3] from the Bokkeveld Beds is identical with our specimen, Sharpe's type being merely the impression of one pair of valves.

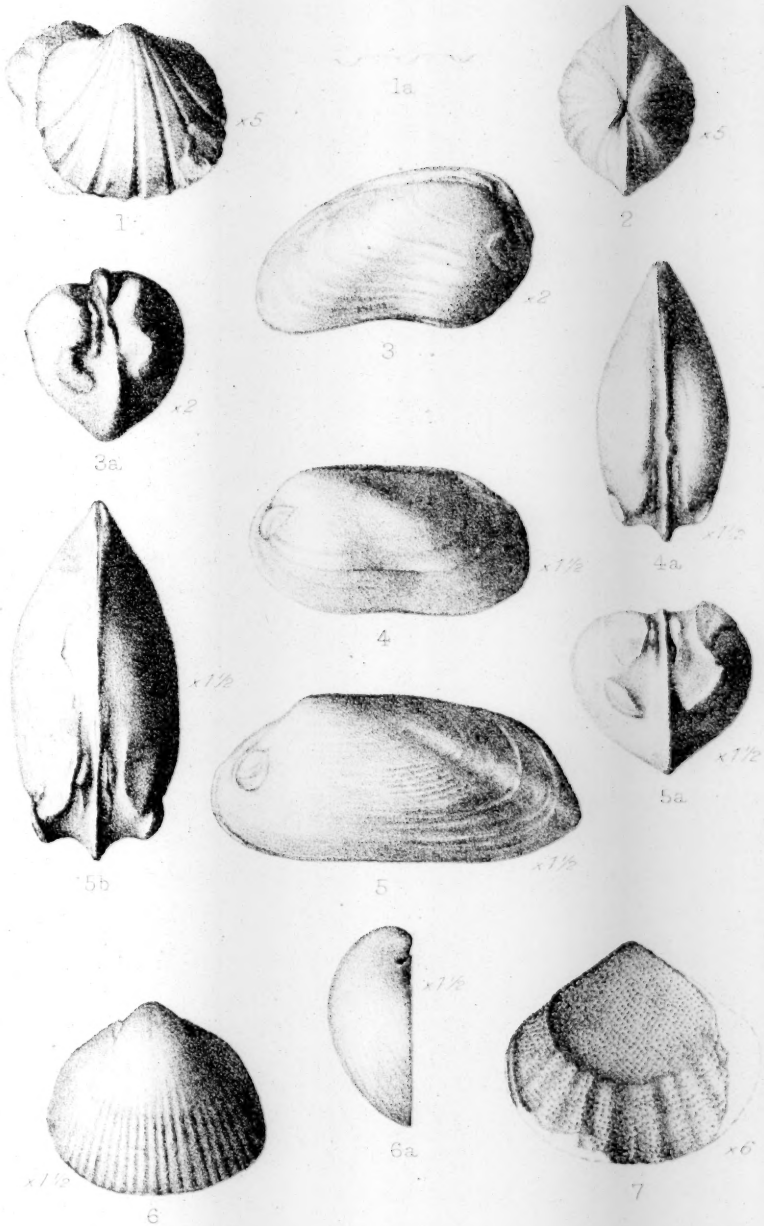
SANGUINOLITES NIGER, sp. nov. (Pl. XVI, Figs. 4, 4*a*.)

Two examples of another lamellibranch from the Zwartberg Pass likewise consist of internal casts, one of which is nearly perfect, but the other has the posterior end broken off. From the former the following description is drawn up:—Shell oblong, upper and lower margins nearly parallel; posterior and anterior ends broadly rounded, the former rather broader and more obtuse. Cardinal margin behind beaks straight and horizontal; inferior margin indented with wide, shallow sinuation in middle, and curving up more gradually in front than behind. Beaks subanterior, broad, obtuse, low, scarcely rising above hinge-line, and directed forwards. A broad, undefined umbonal ridge runs down with decreasing strength to posterior third of inferior margin, and has a weak, shallow depression in front of it corresponding to marginal sinus. Valves moderately convex, most so on umbonal ridge, flattened and compressed behind. Anterior adductor scars deep, oval, situated just below beaks, close to anterior margin. Posterior adductors indistinct. Cardinal and anterior margins thickened internally with elongated, lanceolate, ligamental area behind beaks, and one or two elongated pits between beaks parallel to hinge-line. No teeth present.

Dimensions:

Length	24·5 mm.
Height	14·5 ,,
Thickness	11·5 ,,

[1] Hall: Palæont. N.Y., vol. v, pt. 1 (1883), pl. liii, figs. 9–20.
[2] Beushausen: op. cit., p. 31, pl. iii, figs. 7–9.
[3] Sharpe: op. cit., p. 212, pl. xxvii, fig. 8.



G.M. Woodward del. et lith. West, Newman imp.

Bokkeveld Fossils.
S. Africa.

Locality.—Zwartberg Pass.

Remarks.—The true generic position of this shell appears to be in *Sanguinolites*, following Wheelton Hind's definition.[1] In shape and general characters our species seems to resemble Oehlert's *S. Marsi*,[2] but probably it belongs to a new and undescribed species which may be termed *niger*. I do not think any of the Brazilian or Bolivian forms which Clarke and Ulrich have described and figured come very near it.

SANGUINOLITES (?) ACER, sp. nov. (Pl. XVI, Figs. 5, 5*a*, 5*b*.)

There is another internal cast from Zwartberg Pass which may represent a species of *Sanguinolites*, but its generic position is somewhat doubtful.

Shell elongated oval, twice as long as high; valves strongly convex, most so in anterior two-thirds of shell, posteriorly being somewhat compressed. Anterior end rounded, slightly narrower than posterior end, which is obliquely truncated. Hinge-line gently arched; inferior margin nearly straight, a little concave towards middle. Beaks broad, obtuse, low, situated at about one-fourth the length of the shell from anterior end; obscurely defined, transversely oval lunule in front. Umbonal ridge moderately strong, running from beak to postero-inferior angle, with shallow, undefined, weak depression in front of it reaching sinuation of inferior margin, and a narrow, more defined sulcus behind it running nearly straight back to posterior angle. Anterior adductor scars deep, subtriangular, strongly ridged, situated close to anterior margin and about half-way between beak and anterior inferior angle. Pallial line simple, and at about one-fourth the height of the shell. Posterior adductor scars not visible. Margins of valves between beaks and on anterior end thickened internally and rounded; on umbonal hinge-plate thus formed is a short longitudinal furrow parallel to hinge-line and followed by two or three more or less fused pits. Surface of shell ornamented with rather coarse, raised, concentric ridges swelling out into small irregularly spaced nodules (observed on one fragment of shell adhering to the cast).

Dimensions:

Length	33·5 mm.
Height	16·5 ,,
Thickness	15·0 ,,

Locality.—Zwartberg Pass.

Remarks.—It does not seem possible to determine with certainty the genus of this shell. The ridges and grooves on the surface and the ornamentation suggest *Grammysia*; the internal grooves and pits on the hinge-plate are indistinctly seen, but seem to point to the presence of an internal ligament. The general shape, however, more resembles members of *Sanguinolites*, and for the present it may be left in this genus.

[1] Wheelton Hind: Mon. Brit. Carb. Lamell., vol. i, pt. 5 (1900), p. 361.
[2] Oehlert: Bull. Soc. Géol. France, ser. III, vol. xvi (1888), p. 658, pl. xv, fig. 4.

BRACHIOPODA.

SCAPHIOCŒLIA (?) AFRICANA, sp. nov. (Pl. XVII, Figs. 1, 1*a*, 1*b*, 1*c*; 2, 2*a*, 2*b*; 3, 3*a*.)

Diagnosis.—Shell elongate-oval to subcircular, plano-convex. Pedicle valve inflated, strongly convex, compressed laterally, distinctly keeled and angulated on back; beak large, high, incurved, rising well above strongly curved hinge-line and arching over beak of opposite valve, with sharply angular lateral edges and large concave triangular pseudo-area below it; large triangular delthyrium (? covered by concave plate), with margins slightly infolded; small subapical foramen present in beak. Brachial valve flat or very feebly convex; beak smaller and lower, and less incurved than that of pedicle valve.

Interior of pedicle valve with pair of thick, strong, subparallel or slightly divergent dental plates, slightly concave and closely embracing sides of cardinal callosity of opposite valve (Figs. 1, 1*b*, 1*c*). Muscular impression large, oval, extending about one-third the length of the valve, slightly depressed and margined by weak ridges diverging from bases of dental plates, which are connected by a low, faint, transverse ridge in umbonal cavity; the pair of large elongate diductor scars are distinct in the muscular area, but the adductor scars are not visible.

Interior of brachial valve with large massive umbonal callosity or hinge-plate completely fused with bottom of valve and filling up whole of cavity of beak; anterior face of callosity is vertical, marked with shallow longitudinal groove and deep central pit, and it bears on its free edge a pair of small, short, blunt cylindrical processes (bases of crura) projecting into the pedicle valve (Figs. 1*b*, 1*c*). Muscular impression large, oval, consisting of pair of deeply sunk, oval, posterior adductors indistinctly separated from a pair of rather larger, less sunk, anterior adductors, faintly defined in front; a pair of low, rounded, diverging ridges bound the impression laterally, and a narrow, thin, median ridge, thickest and highest between the posterior adductors, divides it longitudinally.

Surface of shell marked with 30–40 low flattened ribs, closely placed and separated only by narrow grooves. In the internal casts the ribs show more distinctly than on the exterior of the shell itself. A few concentric growth-ridges are present in some specimens. Shell substance thick, massive, impunctate.

Dimensions:

	I.	II.	III.	IV.
Length	... 57	... 53	... *ca.* 52	... 39 mm.
Width	... 32	... 32	... *ca.* 35	... 38 ,,
Thickness	... 33	... *ca.* 34	... *ca.* 32	... 27 ,,

Specimens I and II are in the South African Museum, Cape Town. Specimens III and IV have been presented by the South African Museum to the Sedgwick Museum, and are in the latter.

Locality.—Gouritz River, north of the Langebergen.

Remarks.—Eight specimens of this interesting fossil have been

submitted to me for examination, and all are from the same locality. They are in the condition of internal casts, with the exception of one fragment of a pedicle valve (Pl. XVII, Figs. 3, 3*a*), which has the shell of the beak and of the adjoining portions preserved. It is unfortunate that the available material is not better, but by making casts of the specimens it has been possible to draw up the foregoing description.

The generic position and relations of this fossil are not at once obvious, although the general appearance suggests the genus *Rensselæria*, and certain features recall the imperfectly known genus *Scaphiocœlia* from the Devonian of Bolivia. This genus, of which only one species has been described (*S. boliviensis*, Whitfield[1]), is defined by its author as follows:—"A terebratuloid, brachiopodous shell, having a strongly convex ventral valve and a longitudinally and angularly sulcated dorsal valve, both of which are strongly plicated. Internally the ventral valve has a strong, deep, triangular, byssal opening and muscular seat, and the dorsal has strong crural processes; but the loop or calcified appendages are unknown. Shell structure strongly fibrous, without any puncture under a hand-magnifier." Hall & Clarke[2] quote this description, and remark that the genus may be provisionally regarded as allied to *Centronella* and *Trigeria*. The type-species reaches a size of over 3½ inches in length. Our specimens approach this in dimensions, and possess the large incurved beak, foramen, and apparently open delthyrium indicated in Whitfield's figures. The pedicle valve is likewise the more convex of the valves, but the brachial is merely flattened and not "angularly sulcated." The external ornamentation and structure of the shell appear to be similar, though the surface of our specimens is somewhat abraded.

Internally our shell does not exhibit the perforated hinge-plate of *Trigeria* and its allies; and its massive hinge-plate, not divided down the middle and not supported by septa, removes it from *Rensselæria* and *Beachia*. The muscle-scars are also quite different. The characters and prominence of the muscle-scars in the pedicle valve, and the massive hinge-plate, median septum, and large, well-defined, flabellate, adductor impressions in the brachial valve of *Megalanteris ovalis*, Hall,[3] are recalled by the characters of our species, but we have no evidence that the latter possessed a cardinal process similar to that found in *Megalanteris*. The beak of the pedicle valve is less prominent, and the ornamentation of the surface of the shell different, but these features are of less importance. The stout approximate crura in our shell are not specially distinctive.

On the whole, we seem to have a shell externally resembling in many respects *Scaphiocœlia*, and internally showing many features of resemblance to *Megalanteris*. The ignorance which exists as to

[1] Whitfield: Trans. Amer. Inst. Mining Engineers, vol. xix (1891), p. 106, figs. 1–4.

[2] Hall & Clarke: Palæont. N.Y., vol. viii, Brach. ii (1894), p. 275, figs. 193–196.

[3] Hall: Pal. N.Y., vol. iii (1859), p. 458, pl. 106, figs. 2*a–l*. Hall & Clarke, op. cit., p. 277, pl. lxxvii, figs. 12–22.

the internal characters of *Scaphiocœlia* is unfortunate; but on account of its external resemblance and its typical occurrence in beds of which the fauna has been proved to be closely allied to that of the Cape Bokkeveld formation, we may provisionally assign our species to this genus, and designate it by the distinctive specific name of *africana*. I am inclined to think that the poor specimen which I described[1] as *Rensselœria*, sp. *a*, from Assegai Bosch, Roode Berg, Ladismith, should be referred to this species, or at any rate to this genus; and it is not impossible that the other form described as *Rensselœria*, sp. *β*,[2] may also belong to it; but they are in too poor a state of preservation to establish their position without doubt.

RENSSELÆRIA cf. CONFLUENTINA, Fuchs. (Pl. XVI, Figs. 6, 6*a*.)

There is one tough, grey quartzose sandstone fragment, deeply iron-stained on the surface, from the Gouritz River, north of the Langebergen, which contains two specimens of a subcircular, strongly convex, and radiately ribbed brachiopod. Both specimens apparently represent the pedicle valve, and the better preserved one has a regularly convex, swollen shape, with an incurved, moderately high beak, on each side of which small dental plates are indicated by slits in the cast. The surface of the valve shows no fold or sinus, but is covered by about 40–50 regular, closely placed, simple, radiating, small, rounded ribs. A few concentric growth-ridges are visible towards the margin. The dimensions of this specimen are as follows, the maximum width being anterior to the middle:—Length 18·0 mm., width 19·0 mm., depth (of pedicle valve) 8 mm. Another specimen of approximately the same size from the same locality consists of the internal cast of a complete individual, slightly distorted. The shell is biconvex, the pedicle valve being slightly deeper than the brachial; and the shape agrees with that of the previously described specimen. The oval impression of the diductor muscles in the pedicle valve is strong and deep, and extends about one-third the length of the valve from the beak. In the opposite valve the two pairs of adductors form a subtriangular scar, widening anteriorly; the posterior pair is narrow and deeply sunk, while the anterior pair is wider and less clearly defined. A low median ridge divides the pairs longitudinally. The hinge-plate was deeply cleft, but further details cannot be made out. The ribbing on the surface is the same as in the other specimen.

The true generic position of these brachiopods is somewhat doubtful, but I believe they must be placed in the genus *Rensselœria*. The internal characters, so far as they are known, agree with this genus, and in shape and general features *R. confluentina*, Fuchs,[3] from the Lower Devonian of the Rhenish area, may be compared. This species is described and figured as having a subrotundate outline, with 40–50 ribs on the larger mature individuals, with concentric growth-striæ, and mostly without a median septum in the

[1] Reed: Ann. S. Afr. Mus., vol. iv, pt. 3 (1903), p. 176, pl. xxi, fig. 8.
[2] Ibid., p. 177, pl. xxi, fig. 9.
[3] Fuchs: Jahrb. kön. preuss. geol. Landesanst., xxiv, pt. 1 (1904), p. 50, pl. vii, figs. 7–14; pl. viii, figs. 1–14.

pedicle valve. Probably the poor specimens referred previously by me[1] to *Trigeria* aff. *Gaudryi*, Oehlert, belong to the same form.

If a specific name for this shell is considered desirable, as it is probably distinct from any described by other writers, I would suggest the name *rotunda*, in reference to its shape.

Locality.—Gouritz River, north of the Langebergen.

PTYCHOSPIRA VARIEGATA, sp. nov. (Pl. XVI, Fig. 7.)

In three fragments of the bluish-grey micaceous clay containing *Tentaculites crotalinus* and *Nuculites* cf. *Smithi*, from an "unknown locality," there are the imperfect internal casts and external impressions of a small brachiopod, which, by its shape, plications, and remarkable ornamentation, is closely allied to, though not identical with, *Ptychospira ferita* (Von Buch) of the Middle Devonian of the Eifel. The typical shape of this European species is rather more elongate and less transverse; and it has a few rounded, curved plications, increasing in strength towards the margin, the central one of which in the pedicle valve is straight and grooved down the middle. But in our Cape form all the folds are nearly straight, and there seem to be 3–5 lateral ones on each side of the median one, instead of only 3, though those nearest the hinge-line are very faint and weak. The whole surface of our shell is also covered with small, closely-set pits, arranged mostly in irregular quincunx fashion, but forming radiating rows gently curved upwards near the cardinal angles, and towards the front there is a tendency for 2–3 adjacent pits to fuse and form short broken lines more or less concentric to the margin. A few concentric growth-ridges are also present. The more transverse shape of the shell, the number of folds, their smaller curvature, and the distribution and local fusion of the pits on the surface distinguish this imperfectly known shell from *Pt. ferita*, of which Sandberger[2] has well figured the external ornamentation. The average length of our specimens is about 5 mm., and the transverse width slightly greater.

EXPLANATION OF PLATES XVI AND XVII.

PLATE XVI.

FIG.

1. *Buchiola subpalmata*, sp. nov. × 5. Zwartberg Pass.
1*a*. Ditto. Outline section of ribs to show shape and elevation.
2. Ditto. View of another complete shell from above.
3. *Nyassa arguta*, Hall (?). × 2. Zwartberg Pass.
3*a*. Ditto. Same specimen. × 2. Anterior view.
4. *Sanguinolites niger*, sp. nov. × 1½. Zwartberg Pass.
4*a*. Ditto. Same specimen viewed from above.
5. *Sanguinolites* (?) *acer*, sp. nov. × 1½. Zwartberg Pass.
5*a*. Ditto. Same specimen. × 1½. Anterior view.
5*b*. Ditto. Same specimen. × 1½. Viewed from above.
6. *Reusselaeria* cf. *confluentina*, Fuchs. × 1½. Pedicle valve. Gouritz River.
6*a*. Ditto. Same specimen. × 1½. Side view.
7. *Ptychospira variegata*, sp. nov. × 6. Internal cast of pedicle valve. Locality unknown.

[1] Reed: Ann. S. Afr. Mus., vol. iv, pt. 3 (1903), p. 178, pl. xxi, figs. 11, 12.

[2] Sandberger: Verstein. Rhein. Syst. Nassau, 1855, p. 330, pl. xxxiii, figs. 13*c*, *d*. Hall & Clarke: Palæont. N.Y., vol. viii, Brach. ii (1894), p. 112.

PLATE XVII.

FIG.

1. *Scaphiocælia* (?) *africana*, sp. nov. Nat. size. Side view of internal cast. Gouritz River.
1*a*. Ditto. Same specimen. Anterior view of shell.
1*b*. Ditto. Same specimen, viewed from dorsal (brachial) side.
1*c*. Ditto. Same specimen. Umbonal region of pedicle valve, inverted to show details of structure.
2. Ditto. Another smaller specimen. Nat. size. Side view of internal cast, showing ribbing of shell. Same locality.
2*a*. Ditto. Same specimen. Nat. size. Anterior view.
2*b*. Ditto. Same specimen. Nat. size. Viewed from dorsal side. (The right-hand upper portion of shell is obscured by matrix.)
3. Ditto. Another specimen. Nat. size. Umbonal region of an imperfect individual, with shell adhering to cast of pedicle valve. Same locality.
3*a*. Ditto. Same specimen. Nat. size. Full-face view, showing sharp incurved beak of pedicle valve.

d. diductor muscles; *a*. adductor muscles; *c*. bases of crura; *d.p*. dental plates; *f*. foramen in beak of pedicle valve; *p*. central pit in hinge-plate; *t.r*. transverse ridge in umbonal cavity of pedicle valve; *m.r*. median ridge in brachial valve.

[N.B.—With the exception of the specimens Pl. XVI, Fig. 1, and Pl. XVII, Fig. 3, which are in the Sedgwick Museum, all the above types are in the South African Museum, Cape Town.]

III.—The Origin and Mode of Formation of the Permian Breccias of the South Devon Coast.

By Bernard Hobson, M.Sc., F.G.S.,
Lecturer in Petrology and Geology in the Victoria University of Manchester.

(PLATE XXI.)

AFTER visiting in 1905 the excellent exposure of the Permo-Carboniferous Dwyka Conglomerate, containing glacially striated boulders, overlying glacially striated Barberton beds at the foot of Gotshe Mountain in the Vryheid district of Natal,[1] it occurred to me to examine the Permian breccias of the South Devon coast to see whether I could find any evidence of their being of glacial origin.

The breccias in question have been frequently described, but, so far as I can find, the published information is very vague in some respects, more particularly as to the size of the fragments, blocks, or boulders composing the breccia which, in most cases, are simply described as large or small, than which nothing can be more indefinite.

As large blocks are much more easily transported by ice than by water, I paid special attention to the size of the blocks. The localities visited lie between Roundham Head, Paignton, on the south, and Dawlish on the north, and are shown on the Geological Survey maps (new series), Sheets 339, Teignmouth (1899), and 350 Torquay (1898), and the breccias referred to are those overlying the Watcombe Clay and marked e^2 on the Survey maps.

[1] See G. A. F. Molengraaff, "Geology of the Transvaal," Edinburgh, 1904, p. 66.

H. M. Woodward del. et lith. West, Newman imp.

Bokkeveld Fossils.
S. Africa.

I.—The Size of the Transported Blocks.

Sir H. de la Beche,[1] describing the Red Sandstone Series, says: "On the side of Little Haldon Hill there are blocks of quartziferous porphyry of more than a ton in weight."

Mr. W. Pengelly[2] says: "Again, the trappean masses are not unfrequently of great size. The largest probably occur near the mouth of the Teign, especially in the cliff between Shaldon and the Ness Point. They are more or less ellipsoidal in form, and sometimes measure fully five feet in greatest diameter."

The late Mr. R. N. Worth[3] says: "We have another valuable hint [of their local character] in the fact that these fragments attain their largest size in the vicinity of Teignmouth, and that thence both to the north and south they rapidly graduate downward to very moderate dimensions, and, in fact, into sand. . . . Especially prominent also are the boulders in the Dawlish valley. Blocks occur ranging to four and five feet in diameter."

In order to facilitate reference I have arranged the descriptions of exposures examined in regular order, beginning at the south and proceeding along the coast northwards.

The chief points to be brought out are:—

(1) The size of the largest blocks observed.

(2) The fact that they often occur amid blocks (not matrix) of much smaller average size.

(3) The point referred to by Mr. R. N. Worth that the fragments (particularly of quartz-porphyry) are largest between Bundle Head and the Ness near Teignmouth, and diminish in size both to the north and south.

(4) That the Devonian limestone fragments, abundant (in most cases) to south are comparatively scarce to north of Teignmouth.

In describing the average size of the fragments in the breccia the matrix, which is present in all cases, is left out of account.

1. *Roundham Head, near Paignton.*[4]

At the shore end of the south side of Roundham Head is a very excellent exposure in the cliff, estimated at 50 feet in height. The upper three-eighths of the cliff face consist of breccia, which overlies a bed of rock-sand about half the total height in thickness and showing very clear current-bedding.[5] It in turn overlies another bed of breccia, and the whole series is thrown down to the west by a fault exposed with diagrammatic clearness.[6] This is perhaps the most convincing exposure I saw, proving deposit by water. At this spot the breccia is not coarse. Most of the fragments are from one to four

[1] "Report on the Geology of Cornwall, Devon, and West Somerset," 1839, p. 204.

[2] "The Red Sandstones, Conglomerates, and Marls of Devonshire," pt. ii: Ann. Rept. and Trans. Plymouth Inst., 1862–3, p. 30.

[3] "The Igneous Constituents of the Triassic Breccias and Conglomerates of South Devon": Quart. Journ. Geol. Soc., 1890, pp. 71, 72.

[4] See Plate XXI, Fig. 1.

[5] Pengelly describes and figures false bedding at Slapton, Start Bay, and Goodrington Sands, Torbay: Trans. Plymouth Inst., 1862–3, p. 31.

[6] See W. A. E. Ussher, Geol. of Torquay: Geol. Survey Mem., 1903, pp. 110, 111.

inches across, but I saw a limestone pebble measuring 1 ft. by 4½ in. The fragments, mostly angular, are chiefly Devonian limestone (which occurs *in situ* within ¾ mile). In addition vein quartz and purplish red sandstone occur.

2. *Preston Cliffs (Tor Bay).*

In these cliffs, below the Volunteer Battery, at the northern end of the sea wall, which extends northwards from Red Cliff, six feet of breccia are exposed at the foot of the cliff, overlain by orange-red current-bedded sandstone or rock-sand, and the dip of the beds is gently southwards. (This direction of dip is unusual.) The breccia is fine, the rock fragments being from 1 to 4 inches, exceptionally 6 inches long, and several fragments of the typical red quartz-porphyry, which is a very frequent and characteristic constituent of these breccias, were seen, one of them 4 inches long, besides which purplish sandstone and (not abundant) limestone fragments occur. The small size of the quartz-porphyry and scarcity of limestone fragments are noteworthy.

3. *Petit Tor Crags,*[1] *Babbacombe Bay.*

In the conglomerate of Petit Tor Crags and in the talus of fallen blocks of conglomerate at their foot probably nineteen-twentieths of the subangular fragments consist of grey Devonian limestone, often visibly fossiliferous, besides which there occur reddish quartzite and reddish sandstone and a few pieces of red quartz-porphyry, all in a very hard coarse sandy matrix. The fragments are mostly from 1 to 6 inches in diameter, though limestone boulders up to 1 ft. 3 in. by 1 ft. 1 in. by 8 in. are not uncommon. Thin beds of breccia alternate with layers a foot or two thick of finer material. The abundance of Devonian limestone is not surprising, as it occurs *in situ* in Petit Tor close by.

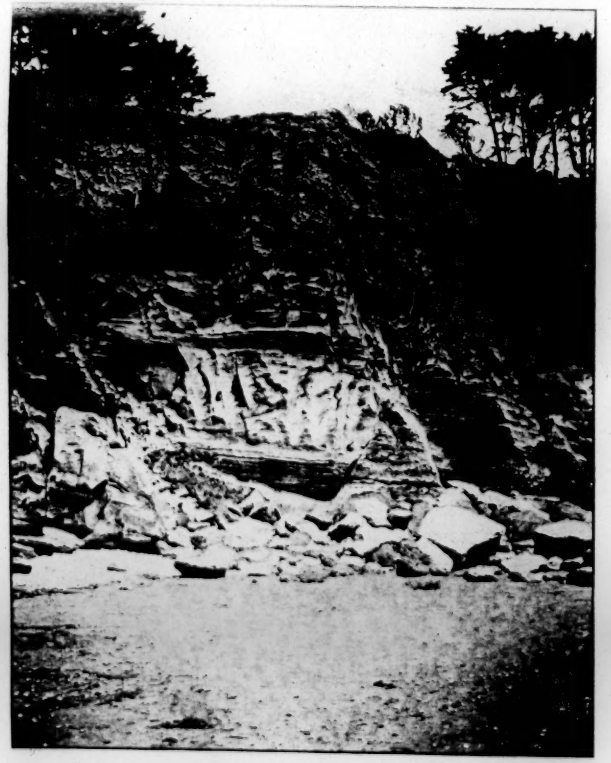
4. *Watcombe Cove.*

At the south side of the cove the breccio-conglomerate is thrown down by a fault against the Watcombe Clay,[2] and dips at 45° northwards. By far the greater proportion of the fragments consist of fossiliferous Devonian limestone, of which an unusually large block measured 1 ft. 10 in. by 10 in. by 6 in. + (partially embedded). Next in abundance (but at a long interval) come fragments of reddish and purplish sandstone, boulders resembling Permian felspathic trap, and a few bits of vein quartz.

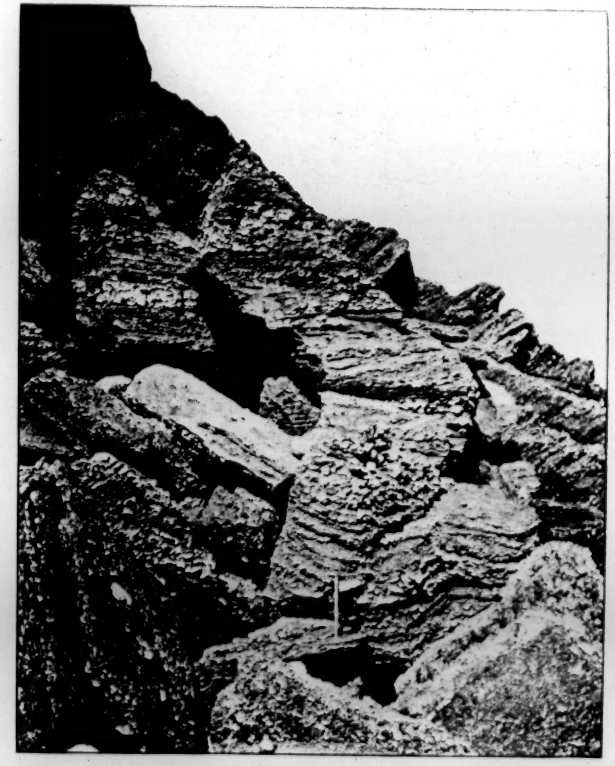
A microscopical section of the matrix of the breccia-conglomerate at Watcombe Cove shows large limestone fragments, bits of slate and grit, many angular quartz sand grains, and abundant fragments of volcanic rock. One of the volcanic fragments is crowded with minute spherulites, showing well-defined black cross by polarized

[1] See Plate XXI, Fig. 2, and for section of Petit Tor see W. A. E. Ussher, Geol. of Torquay, Geol. Survey Mem., 1903, p. 109; and "Coast Section from Babbacombe to Watcombe," by W. A. E. Ussher, Proc. Geol. Assoc., vol. xvi (1900), p. 434.

[2] W. A. E. Ussher, "On the Age and Origin of the Watcombe Clay": Rept. and Trans. Devon Assoc. Adv. Sci., ix (1877), p. 298; also section in Proc. Geol. Assoc., xvi, p. 434.



1.—Permian breccias and interbedded current-bedded rock-sand, traversed by a fault, at the shore end of the south side of Roundham Head, Tor Bay.



2.—Fallen blocks of Permian Conglomerate at Petit Tor Crags, Babbacombe Bay.
(Length of hammer head and haft, 1 ft. 10 ins.)

light, and contains porphyritic brown mica. It closely resembles a spherulitic liparite I collected in the Grand Cañon of the Yellowstone. The most interesting volcanic fragments, however, are those which closely resemble the Permian felspathic traps from the Exeter district, which I described in 1892.[1] One of these volcanic fragments shows felspar laths in an opaque matrix consisting partly of iron-ore and partly of red ferruginous matter. It can be paralleled by my section 897 of olivine basalt from Raddon Quarry, west of Thorverton, six miles north of Exeter, although I must confess that none of the fragments in the conglomerate matrix show the red pseudomorphs after olivine so characteristic of most of the Permian felspathic traps. Another type of volcanic fragment very abundant in the matrix shows felspar laths, iron-ore, brown mica, and abundant faintly greenish short prisms, which appear to be apatite. This rock resembles the one I termed mica-augite-andesite (Mr. Teall[2] terms it biotite-trachyte), especially my section 900 from Killerton Park, 5½ miles N. 33° E. of Exeter, except that the Killerton rock contains augite, which I have not found in the Watcombe fragments.

The late Mr. R. N. Worth[3] also records felspathic traps from the Permian breccias of Torbay and Teignmouth. On the other hand, Mr. W. A. E. Ussher[4] says: "The absence of signs of contemporaneous vulcanicity in the New Red Rocks of the area [Geol. Survey Map, new series, sheet 350, Torquay] is accounted for by their evident attenuation through a conformable overlap, as they are traced northward towards Exeter, the volcanic horizon being higher in the series than the strata represented on the map."

Three alternatives occur to me—either Mr. R. N. Worth and I are mistaken in our identification of Permian felspathic traps in the breccias, or Permian felspathic traps may occur *in situ* beneath and hidden by the breccias, or Mr. Ussher may perhaps be mistaken in considering that they lie at a higher horizon.

5. *Cove ¾ mile south of Bundle Head.*

Here, again, the Devonian limestone fragments in the breccio-conglomerate still form a majority: the largest (subangular) limestone block observed measured 1 ft. 4 in. by 1 ft. 1 in. by 8 in.; an average fragment would be about 3 inches across. Fragments of red and purple sandstone, quartz-porphyry and so-called lydian stone[5] occur. A subangular block of quartz-porphyry measuring 1 ft. by 6 in. by 11 in. + (partially embedded) was observed, and about a dozen smaller quartz-porphyry blocks occurred within three yards of it. The rock fragments here are on the whole smaller than at Petit Tor Crags and Watcombe Cove. Seams of breccia alternate

[1] Quart. Journ. Geol. Soc., p. 496.
[2] Ussher & Teall, Geol. of Exeter: Geol. Survey Mem., 1902, p. 78.
[3] Quart. Journ. Geol. Soc., 1890, p. 76.
[4] Geol. of Torquay: Geol. Survey Mem., 1903, p. 112.
[5] Rev. J. J. Conybeare, "On the Red Rock Marle, or Newer Red Sandstone": Annals of Philosophy, N.S., vol. i (1821), p. 257; Conybeare & Phillips, Geol. England and Wales, pt. i (1822), p. 294; also Ussher, Geol. of Torquay, 1903, p. 111, line 4.

with seams of sandstone and dip slightly southwards. There is much more matrix and a smaller quantity of fragments than in the two preceding exposures.

6. *Bundle Head and the Ness.*[1]

As Bundle Head is half a mile south of the Ness, it should, strictly speaking, be described first, but it is more convenient to describe the two as approached from Teignmouth.

Crossing the Teign at the ferry from Teignmouth to Shaldon, I walked to the Ness (at the mouth of the Teign), passing on the way several large blocks of quartz-porphyry on the beach. The conglomerate at the base of the Ness contains a considerable proportion of Devonian limestone, often visibly fossiliferous, purplish-red sandstone, some red quartz-porphyry, and a few fragments of the so-called lydian stone. Going southward round the foot of the Ness, I found lying loose upon the beach a block of red quartz-porphyry measuring 3 ft. by 2 ft. 6 in. by 2 ft. 8 in., and eighteen paces to south of it another block of the same rock 2 ft. 10 in. by 2 ft. 4 in. by 2 ft. 4 in. Both of these blocks agreed petrographically with the red quartz-porphyry blocks embedded in the conglomerate. This red quartz-porphyry is very characteristic of these Permian conglomerates and breccias, and its petrographical characters will be referred to later. A few yards south of the last-mentioned loose block is a mass of the same red quartz-porphyry 3 ft. 6 in. by 2 ft. by 2 ft. + partially embedded in the conglomerate, and another few yards south a similar block 2 ft. 10 in. by 2 ft. by 1 ft. 5 in. also in the conglomerate. A thousand paces south of the block last mentioned, at a promontory which is, I believe, Bundle Head, and lying among great fallen blocks of the conglomerate, is another loose block of red quartz-porphyry 5 ft. by 3 ft. by 3 ft.; six paces from it is another similar block 3 ft. by 3 ft. 6 in. by 2 ft. 9 in. Only 23 paces further south is a block of Devonian limestone 2 ft. 6 in. by 1 ft. 6 in. by 1 ft., apparently embedded as to its lower surface in the conglomerate, though it may have been squeezed down into it by the action of the sea. Yet most of the blocks in the conglomerate hereabouts are only 3 to 6 inches in diameter. Five paces from the last limestone block another, roughly elliptical in form, 3 ft. 6 in. by 2 ft. 8 in. by 1 ft., lies loose on the beach. Eleven paces from the limestone block last mentioned (and lying on the top of fallen conglomerate masses) are two blocks of red quartz-porphyry lying close together, one measuring 4 ft. 6 in. by 4 ft. by 2 ft., the other 4 ft. by 4 ft. by 3 ft. Eight paces further south is the largest boulder (of any rock) I saw on the South Devon coast, a block of red quartz-porphyry, 5 ft. 4 in. by 5 ft. by 3 ft. 6 in., to which I shall refer again. It lies loose on the beach amid huge fallen masses of conglomerate. Four hundred and fifty paces south of the last (after passing several others) I found lying loose on the

[1] See G. W. Ormerod, "On the Murchisonite Beds of the Estuary of the Ex, and an attempt to classify the Beds of the Trias thereby": Quart. Journ. Geol. Soc., 1875, p. 349, and section from Minnicombe to Lympstone, fig. 3.

north side of a scar of conglomerate a similar boulder 3 ft. 6 in. by 2 ft. 9 in. by 2 ft. 9 in.; 120 paces further south two similar blocks, 2 ft. 4 in. by 3 ft. by 1 ft. 4 in. and 2 ft. by 2 ft. by 1 ft. 6 in. respectively. I have no doubt that all the loose blocks hitherto mentioned are derived from the neighbouring Permian conglomerate, as they agree lithologically with the blocks in the conglomerate. Lying, as most of them do, amongst fallen masses of conglomerate, they do not appear to have been appreciably worn by the action of the existing sea. All the quartz-porphyry blocks at Bundle Head and the Ness are subangular. It is on account of their exceptionally large size, and not as average specimens of the blocks composing the conglomerate, that they are referred to.

7. *Teignmouth.*

On walking along the promenade (sea-wall) at Teignmouth towards Dawlish, one sees the breccio-conglomerate exposed at the back of the promenade just before it reaches the Great Western Railway. The rock fragments in the breccio-conglomerate there are generally 2 to 4 inches across and smaller. Quartz-porphyry is common; a subangular block of it measured 1 ft. 4 in. by 1 ft. 4 in. by 1 ft. + partially embedded. Purplish-red sandstone fragments are abundant, and the so-called lydian stone occurs. No limestone was observed;[1] indeed, the difference between the abundance of limestone fragments at the Ness on the south side of the Teign and its comparative scarcity at and north of Teignmouth is such that perhaps one may suspect that the beds on the north of the river are faulted down compared with those at the Ness.

8. *Along the Great Western Railway between Teignmouth and Dawlish.*

North of Teignmouth, at the 208½ mile-post (from London) on the railway, the breccia has an apparent dip of 16° to 20° northward, and consists of distinctly angular fragments, mostly about 3 inches or less, but running up to 7 inches, and exceptionally, in the case of a quartz-porphyry block, 18 inches in diameter. The fragments consist of grey quartzite, greenish quartz-porphyry weathering reddish, the typical red quartz-porphyry, purplish-red sandstone, black quartzite. No limestone was observed, though, as remarked in reference to Teignmouth, a minute search might discover some.

Where large boulders occur in these South Devon breccias they, so far as observed, lie with their longer axes parallel to the bedding-planes[2]—for instance, at a point 150 paces south of the 208¼ mile-post (G.W.R.) a quartz-porphyry boulder 2 ft. 8 in. by 9 in. by 1 ft. 4 in. + partially embedded, elliptical in form, moderately well rounded, lies in the breccia 20 to 30 ft. above the rails; 5 paces north of it is a subangular block of fine-grained mottled red sandstone 2 ft. 4 in. by 1 ft. 6 in. + partially embedded, and about

[1] Very likely a minute search might discover some.

[2] Pengelly says: "The pebbles lie with their longest axes parallel to the planes of bedding" ("The Red Sandstones, etc., of Devonshire," pt. ii: Ann. Rept. and Trans. Plymouth Inst., 1862–3, p. 31).

15 ft. above it another inaccessible block of rock over 1 ft. in diameter. All these blocks lie parallel to the bedding-planes, which have an apparent dip of 20° northwards. No evidence of a boulder dropped by ice and bending down the laminæ below it, as described by Professor James Geikie[1] as occurring near Uddingston, Lanarkshire, was anywhere seen. At the 208¼ mile post (G.W.R.) several fragments of limestone, one of them 11 inches long, elliptical, fairly well rounded, occur in the breccia; and 4 paces north of the 207¾ mile-post limestone fragments up to 6 inches long occur in the breccia, which is here coarser than it is nearer Teignmouth. At 124 paces north of the 208 mile-post a block of reddish quartz-porphyry 2 ft. by 1 ft. 3 in. occurs; north of the 207¾ mile-post at 12 paces is a boulder of typical red quartz-porphyry 1 ft. 4 in. by 8 in.; at 130 paces a (quartz-porphyry) block 3 ft. by 2 ft. by 1 ft. 6 in. +; at 243 paces a (quartz-porphyry) block 2 ft. 2 in. by 1 ft. All these four blocks are in the breccia. At the north end of Parson's Tunnel (the first north of Teignmouth) fragments of red quartz-porphyry, quartz-porphyry with greenish groundmass, grey quartzite, weathering purplish, and limestone occur in the breccia. At the south end of the second tunnel from Teignmouth (129 paces north of the 207 mile-post) the breccia is not at all coarse; most of the fragments are not more than 2 inches, a few 4 inches, and in rare cases 6 inches across. Just north of Dawlish station at the 206 mile-post the rock consists of alternating beds of red sandstone and breccia, each 4 inches to 3 feet thick. The breccia consists of small angular fragments, mostly 1 inch in diameter or less, but a few 3 to 5 inches across.

II.—The Origin of the Quartz-porphyry Blocks.

The late Mr. R. N. Worth has decribed[2] the red quartz-porphyry so common in the breccia as a "Deep-red porphyritic rock, varying to red brown and purplish brown; compact felsitic base with porphyritic quartz and felspar, some of the latter kaolinized, some Murchisonite; occasionally, but not invariably, some mica. This is the so-called red 'porphyritic trap' more or less characteristic of the conglomerates within our area, from Torbay to the Crediton valley, and the origin of which has been a special topic of discussion. Save in colour, however, these fragments are hardly distinguishable from some Dartmoor elvans." A microscopical section which I have had made from a block, which measures 1 ft. 4 in. by 9½ in. by 5 in. + and still remains embedded in the conglomerate, at the Ness opposite Teignmouth, shows phenocrysts of quartz, felspar, brown mica, and apatite. The felspar consists chiefly of much altered large porphyritic crystals without any visible twinning lamellæ, and of much scarcer, smaller, and fresher porphyritic crystals of lath-shaped form, also not visibly twinned. The mica phenocrysts are sometimes inclosed in the larger felspars. The ground-mass appears by reflected light reddish, by transmitted light brownish, owing to ferruginous matter.

[1] "The Great Ice Age," 3rd ed. (1894), p. 274.
[2] Quart. Journ. Geol. Soc., 1890, p. 75, item 29.

By polarized light it is not isotropic, but cryptocrystalline, and in some parts microcrystalline, in which case it consists of quartz and felspar. I have written to Mr. R. Hansford Worth to inquire whether he knows of any definite locality where this rock occurs *in sitû*. He has kindly sent me a specimen of the felsite from the Slope of Legis Tor (N.N.E. of Plymouth), long. 4° 0′ 23″, lat. 50° 23′ 20½″, described by him.[1] It bears some resemblance to the red quartz-porphyry of the Permian breccia, but it differs in containing "frequent spheroids and aggregates of minutely crystalline schorl," in its ground-mass being more granular (distinctly crystalline) and salmon-coloured instead of compact and chocolate red, and in having, according to Mr. Worth, a specific gravity of 2·57, whereas I found for a specimen from the (sectioned) block *in sitû* in the conglomerate at the Ness 2·49. Mr. R. H. Worth writes to me: "But from Legis Tor there comes another variant. The same red ground-mass. Porphyritic quartz well developed, and cream-coloured felspars numerous and prominent. Kaolinize these felspars and you have one of the Teignmouth rocks at once." Though I doubt whether an exact match would be thus obtained, I think it likely that when Dartmoor is more thoroughly known such will be found. The nearest part of the granite mass of Dartmoor is nine miles from the Ness. In 1892 I mentioned[2] that "A mass of genuine quartz-porphyry measuring about 4 feet by 1 foot is exposed on the west side of the road opposite to the entrance gate of Dunchideock House [3½ miles south-west of Exeter], but it appears to belong to the New Red Breccia." I have no note as to whether this was the typical red quartz-porphyry, but it is only 4½ miles from the Dartmoor granite.

III.—The Possibility of Transport by Water of the largest Blocks observed.

If we assume, for the moment, that the blocks in the breccia and conglomerate have been transported by water, it is of interest to calculate the velocity of the current required to move the largest block of quartz-porphyry observed near Bundle Head. The dimensions of 5 ft. 4 in. by 5 ft. by 3 ft. 6 in. give 93⅓ cubic feet. Taking its specific gravity at 2·49 (that of the red quartz-porphyry block *in sitû* in the conglomerate) and the weight of a cubic foot of water at 62·4 lbs., we obtain 6 tons 9 cwt. 1 qr. 26 lbs., or, if we deduct 10 per cent. on account of irregular form, 5 tons 16 cwt. 2 qrs. 4 lbs. for its probable weight. Prof. A. Penck[3] gives a formula from which the velocity of current at which a cube of rock with a given length of side l will just remain motionless on a horizontal surface can be calculated; it is $v = 3{\cdot}86\sqrt{l}$. If we take the contents of the block to be 93 cubic feet it would correspond to a cube of 4·531 ft. or 1·381 metre side. The required velocity is 22·33 kilometres,

[1] "The Petrography of Dartmoor and its borders": Trans. Devon. Assoc. Adv. Sci., vol. xxxiv (1902), p. 519.

[2] Quart. Journ. Geol. Soc., 1892, p. 506.

[3] "Morphologie der Erdoberfläche" (1894), vol. i, p. 280, line 18.

or 13·84 miles per hour. Penck assumes a specific gravity of 2·2, and that of the quartz-porphyry may be taken as 13½ per cent. higher; but having made no deduction for its irregular form in calculating its contents, the result will be approximately correct, so that a current of 14 miles an hour would move it from a horizontal surface. According to Prof. F. Ratzel[1] torrents may attain a velocity of 6 metres per second (21·6 kilometres per hour). Sir A. Geikie[2] says even the current "of a torrent does not exceed 18 or 20 miles in the hour." It is therefore quite possible that the block was transported by water.

IV.—The Mode of Formation of the Breccias.

Mr. W. Pengelly[3] seems to have regarded the breccias as due to marine action. He says, "The aggregation, however, does not appear to be such as would have resulted from the action of a stream or current; it rather indicates the agency of waves on an open beach." He also assumes that the beds were deposited horizontally, and not inclined as in a delta face, for he gives[4] a table of 34 observed dips from which he calculates the mean amount of dip at 15½° and the mean direction between Saltern Cove and Flat Point (Straight Point) as N. 44½ E. true. From these data he calculates[5] that the thickness between Goodrington Sands and Straight Point is four miles, to which he adds 1½ miles for the thickness between Straight Point and Charton Bay, giving 5½ miles for the New Red Rocks as a whole, while Mr. Ussher[6] calculates the total thickness of the New Red Rocks of Somerset and Devon at 3,280 feet, though he says 2,500 feet appears a more likely estimate.

Mr. Pengelly seems to have had some misgivings as to the beds having been deposited horizontally, for he quotes[7] Sir Charles Lyell's well-known description of inclined deltaic deposits at Monte Calvo, near Nice,[8] but adds, "Possibly something of this kind may have occurred in the formation of the Devonshire Trias; nevertheless, I am not aware of a single fact on which to base such an hypothesis."

Mr. Jukes-Browne[9] quotes the same account from Lyell, and says that "the coarse sandstones of Teignmouth and Dawlish, with their angular fragments of local rocks, seem to be torrential deposits of this kind."

In the account of the "Excursion to Newton Abbot, Chudleigh, Dartmoor, and Torquay"[10] there occurs the following passage with

[1] "Die Erde und das Leben" (1902), vol. ii, p. 86.
[2] "Textbook of Geology," 3rd ed. (1893), p. 376; 4th ed. (1903), p. 487.
[3] "The Red Sandstones, Conglomerates, and Marls of Devonshire," part ii: Ann. Rept. and Trans. Plymouth Inst., 1862-3, p. 31.
[4] Loc. cit., p. 29.
[5] Same paper, part iii (1864-5), p. 40.
[6] "On the Triassic Rocks of Somerset and Devon": Quart. Journ. Geol. Soc., 1876, p. 392.
[7] Loc. cit., p. 45.
[8] "Elements of Geology," 6th ed. (1865), p. 18.
[9] "The Building of the British Isles," 2nd ed. (1892), p. 168.
[10] Proc. Geol. Assoc., vol. xvi (1900), p. 434.

regard to the Oddicombe Cliffs: "Mr. Hunt, turning to the cliffs, remarked that the conglomerates were too angular and irregular for marine action, and on too vast a scale for river action. He knew of no agency to which they could be attributed. Mr. Teall at once pointed out that similar accumulations were known in the Himalayas, where the disintegration of strata exceeded the available transport; the conglomerates were torrential."[1] To come to my own observations—At every locality on the coast visited there was clear evidence that these breccias and conglomerates have been deposited by water. The section at Roundham Head, Paignton, first described, is perhaps the most convincing exposure, but at every locality the bedding in the breccias and conglomerates is clearly seen.

The fact that the large boulders in the breccia lie with their longer axes parallel to the bedding-planes has been mentioned in describing the section between Teignmouth and Dawlish. Well-rounded pebbles like those of a marine shingle beach or of many rivers are exceedingly uncommon. Most of the fragments are either angular or subangular, and this, together with their general local character, is against their having been transported far. Their angular character may be due to the action of frost. On none of the boulders or fragments did I observe any striæ which I could regard as being of glacial origin. In favour of their being deposited by torrents and in originally inclined beds of deltaic character, is the huge size of some of the blocks occurring amongst much finer material, for it is difficult to imagine two such contradictory conditions occurring in combination as a current of torrential velocity flowing far over a comparatively horizontal surface of deposit, and at the same time transporting huge blocks. On the other hand, it is a very remarkable fact that just where the largest blocks occur at the Ness and Bundle Head there is a gentle syncline with horizontal beds in the centre and a gentle dip to N.N.E. and S.S.W. on the respective sides (shown on Geol. Survey map).[2] Here, if anywhere, one would have expected a deltaic angle of dip. This is a point in favour of possible transport by ice. Unless this be considered an exception, no definite evidence in favour of glacial action in transporting the fragments in the breccias was found. This fact, however, would not exclude the possibility that the breccias might be of fluvio-glacial origin. Not only have they been deposited by, but probably in, water. This is indicated by the frequent current-bedding, and by the presence at West Town (Ide) and Pocombe, near Exeter, etc., of sandstone veins[3] in the contemporaneous lavas. It would be rash to conclude that evidence of glacial conditions may not yet be found by local geologists who can examine the contact of the breccia with the underlying Devonian and Carboniferous rocks, and might possibly

[1] See also Rev. Dr. A. Irving, Quart. Journ. Geol. Soc., 1888, p. 157.

[2] Pengelly (Trans. Plymouth Inst., 1862–3, p. 29) gives the dip at Ness Point as 5° to N. 129 E. mg. = E. 15½° S. true.

[3] Ussher, "Geology of Exeter": Geol. Survey Mem., 1902, p. 59. B. Hobson, "Basalts and Andesites of Devonshire, etc.": Quart. Journ. Geol. Soc., 1892, p. 500.

find striæ. Finally, it may be well to add that no attempt has been made to give an exhaustive list of the rocks represented by fragments in the breccias at any locality, and that while all the exposures described are in the breccia and conglomerate e^2, those to the north are usually on a higher horizon than those to the south, owing to the prevailing north-easterly dip.

IV.—On the Carboniferous Basement Beds at Ingleton.

By Cosmo Johns, M.I.Mech.E., F.G.S.

DURING the Spring meeting of the Yorkshire Geological Society at Pateley Bridge it was suggested that, as a first step towards the zonal classification of the Lower Carboniferous rocks of Yorkshire, it would be desirable to determine the horizon of the basement beds at Ingleton as compared with the Avon sequence. As the Yorkshire Naturalists Union had arranged a meeting at Ingleton for May 12–14th, the geological route was arranged so as to include as many exposures of the basement beds as possible. The result of the observations made then and during subsequent visits is the subject of this communication.

The district investigated is so well known and has been described or noticed by so many workers that a list of references would be out of place in a short note like this. It does not appear that any previous attempt has been made to determine the exact horizon of these particular beds. They are cut off towards the south by the North Craven Fault, but are well exposed at Norber, on both sides of Ingleton Dale, and also in Thornton Dale below Thornton Force. The beds are best seen in Ingleton Dale, and can be easily traced by the line of springs which follow approximately the 800 foot contour-line on both sides of the valley. The structural features are simple; the basement beds follow the uneven lines of the pre-Carboniferous land surface. These older rocks are folded and denuded, so that they now stand almost vertical with a strike averaging north-west and south-east. A series of later folds along an east and west axis probably causes a repetition of the beds, and all that can be said at this stage is that we have here probably a complex of rocks older than is generally considered.

Above the basement beds come the Great Scar Limestone, then the Yoredale Series, while a capping of Millstone Grit appears on the highest hills. These beds lie almost horizontal, are practically undisturbed by faults, and, except for an almost imperceptible dip to the north-east, remain just as they were deposited. The basement beds themselves consist of a conglomerate of varying coarseness, replaced here and there by pure limestone. The conglomerate generally appears in the hollows of the pre-Carboniferous floor, while the crest of the eminences are often covered with limestone bands free from included pebbles. Quartz pebbles of all sizes are abundant, and layers of conglomerate are often separated by limestone bands. At the foot of Norber, where 25 feet of basement beds appear, the

lower series of fine conglomerate with well-rolled pebbles of the older grits is interstratified with dark limestone bands, and is succeeded by a very coarse conglomerate with large angular boulders of grit, proving that the old land surface was still undergoing denudation somewhere. No Carboniferous Limestone inclusions were found, though carefully looked for. This would indicate that the older land surface was being progressively submerged.

Fossils were only collected from the actual basement beds, and from those exposures where their relationship to the older rocks could be made out. Corals and Brachiopods were specially searched for in view of the remarkable success that has attended Dr. Vaughan's adoption of them in his zonal classification[1] of the Lower Carboniferous rocks of the Bristol area. The successful application of the same methods in the Pendine, South Wales,[2] Mendips,[3] East Derbyshire,[4] and Rush, co. Dublin,[5] made it all the more desirable to commence the investigation of the Yorkshire area north of the Craven faults.

Corals were found in nearly every exposure, but the Brachiopods were very badly preserved. Nothing but indeterminable fragments were found at Norber or the eastern side of Ingleton Dale. Larger fragments and a few fairly well preserved specimens were obtained from the western side, chiefly from exposures opposite the 'Granite' Quarry. Fragments of *Bellerophon* sp. were obtained on both sides of the Dale. Large *Euomphali* were observed in sections near the waterworks.

It had been stated that a limestone band[6] with *Lithostrotion basaltiforme* appears in the conglomerate at Fox Holes. This would seem to be an error. This species was not observed in any of the exposures visited, but as it was seen in the stone walls a search was made at Norber, and it was found plentifully *in sitû* about 125 feet above the basement.

From Dr. Vaughan's correlation note below it will be seen that the horizon of the Ingleton basement beds is equivalent to the top of the *Syringothyris* zone and the base of the *Seminula* zone, or C_2 and S_1 of the Bristol sequence. It corresponds to the break in the faunal succession[7] dividing the lower (Clevedonian) from the upper (Kidwellian) there. It also approximates to the time of volcanic activity at Weston.[8] The striking conglomerate and very probable unconformity[9] at Pendine in South Wales is of the same age; while the Rush[10] conglomerate of co. Dublin is also synchronous. Thus

[1] Quart. Journ. Geol. Soc., 1905, p. 181 et seqq.
[2] Summary of Progress, 1904, p. 43.
[3] Quart. Journ. Geol. Soc., 1906, p. 324 et seqq.
[4] Wedd: Quart. Journ. Geol. Soc., 1906, p. 379.
[5] Quart. Journ. Geol. Soc., 1906, p. 275 et seqq.
[6] Trans. Leeds Geol. Assoc., part v, p. 26.
[7] Quart. Journ. Geol. Soc., 1905, p. 263.
[8] Ibid., p. 250.
[9] Summary of Progress, 1904, p. 44.
[10] Quart. Journ. Geol. Soc., 1906, p. 288.

the final collapse of the pre-Carboniferous land surface at Ingleton, north of the Craven faults, was contemporaneous with widespread disturbances extending from Ireland into Wales, and was indicated in the Bristol area by the outpouring of the Weston lava.

The widespread disturbances already referred to would naturally follow or accompany the final breakdown of the ancient land surface in the north, which had remained unsubmerged during the whole of the Old Red Sandstone and Clevedonian periods. That earth-movements of such magnitude over such a wide area should occur at the horizon which marks the faunal break at Bristol, and be indicated by practically the same faunal assemblage at places like Rush and Ingleton, affords perhaps the best proof of the correctness of the zonal classification employed.

An investigation of the faunal succession of Ingleborough and the relation of the various zones to the lithological divisions seen in the neighbouring dales is in progress.

The writer desires to thank Dr. Vaughan for determining the fossils, and for the note on the faunal correlation below. He would also like to express his indebtedness to Mr. W. Robinson, of Sedbergh, for his valuable assistance during the several visits made to the district.

NOTE BY ARTHUR VAUGHAN, B.A., D.Sc., F.G.S.

FAUNA of the basement beds at Ingleton (Preliminary Notice).[1]

Corals.

Syringopora cf. ***distans*** : abundant.
S. cf. ***reticulata*** : common.
Michelinia (cf. ***M. megastoma***) : fragmentary.
Caninia (cf. ***C. cylindrica,*** mut. S_1) : common.
Campophyllum (?).
Cyathophyllum ϕ : abundant.
Lithostrotion cf. ***Martini*** : common only on east side of Ingleton Dale.
L. sp. (compare form common at Giltar, near Tenby).
Clisiophyllid (cf. ***Carcinophyllum mendipense***) : common.

Brachiopods.

Productus (cf. ***P. θ*** and ***P. corrugatus,*** mut. C) : abundant but fragmentary.
Papilionaceous ***Chonetes*** : common.
Schizophoria resupinata : one fragment.
Bisulcate ***Spirifer*** : fragmentary.
Spiriferid (? ***Spiriferina***) : fragmentary.
Athyris cf. ***expansa*** : common.
Seminuloid Athyrids : fragmentary.

[1] Before a final opinion can be expressed as to the exact position which these beds occupy in the Avonian sequence, it will be necessary to have several of the corals sliced, and to study the Brachiopod fragments more minutely. I do not, however, anticipate that the result of such further work will in any way affect the main conclusion which is here stated.

Gasteropods.

Bellerophon: common. (The fragments agree with the form which is abundant in the upper part of C in the fact that, whereas the young stage exhibits a sulcate periphery, the adult is strongly keeled.)

CORRELATION.

Were such a faunal assemblage as that cited above met with in the South-Western Province, the level at which it occurred would unhesitatingly be referred to the top of the *Syringothyris* zone and the bottom of the *Seminula* zone (C_2–S_1), that is, to the middle of the Avonian sequence. This correlation does not rest solely upon the close similarity of the Corals and Brachiopods to forms which characterize the C_2–S_1 level in the South-Western Province, for the conclusion is confirmed by *the absence of any Brachiopod or Coral which is known to be confined to higher levels.* Assuming, then, that the above correlation is correct, the conglomerate at the base of Ingleborough was deposited at the same time as the conglomerates of Pendine[1] (north of Tenby) and of Rush[2] (co. Dublin).

Hence we owe to Mr. Cosmo Johns a new and an important page in the history of the widespread Mid-Avonian movement.

REVIEWS.

I.—THE FACE OF THE EARTH. By EDWARD SUESS, Professor of Geology in the University of Vienna. Translated by HERTHA B. C. SOLLAS, Ph.D., of Newnham College; under the direction of Professor W. J. SOLLAS, LL.D., F.R.S., etc. Vol. ii. 8vo; pp. vi, 556, with 3 plates, and 42 other illustrations. (Oxford: at the Clarendon Press, 1906. Price 25*s.* net.)

IT is a privilege for which many of us cannot be too thankful, to be able to read in clear and well-chosen language the story unfolded by Suess of the physical history of the Earth. We drew attention in the GEOLOGICAL MAGAZINE for May, 1905, to the translation, by Dr. Hertha Sollas, of the first volume of "Das Antlitz der Erde"; we have now the satisfaction of notifying the publication of the second volume. The previous work, divided into two parts, dealt with the Movements in the Outer Crust of the Earth, and with Mountain Ranges. The present work (part 3) deals with the Sea. The subject is introduced to us in pleasant, not to say poetic language: "We have descended from the mountains and stand on the sea-shore. The eye roams unchecked over the vast expanse of waters. A great wave approaches and seems about to reach us; suddenly its crest curls over, it plunges downwards, and with a dull roar sweeps a little further on without wetting our feet. Then the water streams

[1] Summary of Progress, 1904, p. 44.
[2] Quart. Journ. Geol. Soc., vol. lxii (1906), p. 285.

back, and a long green ridge of seaweed remains to mark the limit of its advance. Soon a second wave follows, then the third, and from time to time one somewhat higher than the rest, which whirls the seaweed further up the beach, and drives us back towards the foot of the cliff."

We are then drawn to examine traces of an older strand, standing high above the existing level of the sea, and to study the history and origin of the displacements of the strand-line. In order to avoid "the adventurous sea of theories for the solid ground of fact" the author uses for the older term "elevation of the land" the *negative displacement of the strand-line*, and for "subsidence of the land" the *positive displacement of the strand-line*.

We are then led to consider the outlines of the Atlantic and Pacific Oceans, and of various lakes and islands. We are, in fact, conducted all over the world, from Greenland to Borneo, to Cochin China and Australia. The characters of the strata forming the lands, and the folds and disturbances to which they have been subjected, are treated in remarkable detail, considering the vastness of the area. The tilted strata of some lands, the horizontal beds of others; the distribution of the formations, the overlaps; the changes in fauna that were due to retreat of the sea or to incoming of fresh-water conditions, are among the many topics discussed. Oscillations of relative level of land and water are considered in reference to detrital and calcareous material, and to the sequence of deposits that make up the geological formations.

In this way the accumulations formed in Palæozoic, Mesozoic, and Tertiary seas are described. The later evidences of physical changes afforded by the Temple of Serapis and by the Baltic and North Seas are discussed at some length.

While the margins of the great oceans are seen to be of different ages, the basins are recognized as sunken areas, and "the wedge-like outlines of Africa, India, and Greenland, all pointing towards the south, find their explanation in the conjunction of fields of subsidence which reach their greatest development in the same direction."

It is difficult to give more than a bare outline of the subjects discussed in this volume, but stratigrapher and palæontologist, geographer and petrologist, will all find matters of abundant interest. The pity is, as we before stated, that no index is given. The ever-increasing literature precludes time being given by all geologists to the perusal of a work like the present. There are particular points or sections that specialists may desire to consult; to them an index would have been most useful. The persistent reader would have been thankful also, as new terms are introduced, and it is not always easy to remember the explanation.

Despite this drawback we must return thanks to the translator and her gifted father for the pains bestowed on the work, and to quote again, from the concluding part of the volume: "Our voyage of inquiry through libraries and literature is now at an end, and we return to the sublime spectacle which served us as our starting-point,

the beach and the long inflowing roll of the ocean waves. Still, the mighty chorus resounds; still, and at the same level, the rising tide pauses before it recedes, and the ebb before it returns. And at this same level the ebb and flood have paused, without sensible change, as far back as man can penetrate into the past of his own race."

II.—Albert Gaudry. Fossiles de Patagonie. Les Attitudes de quelques Animaux. Annales de Paléontologie, publiées sous la direction de Marcellin Boule. I: pp. 1–42, 53 text-figures. 1905.

THIS second part of Professor Gaudry's "Fossiles de Patagonie" is, like the first,[1] chiefly synthetical, and, accordingly, the majority of the numerous figures are more or less restorations. The reader who, after enjoying the author's brilliant synthesis, wishes to fully appreciate his work, is referred to the originals in the Paris Museum: "il sera d'ailleurs facile de vérifier mes interprétations sur les pièces du Muséum." Doubtless it is an easy matter for those who are on the spot; unfortunately, in no other European museum is there an equally rich collection of Tertiary mammals from Patagonia. That is not Professor Gaudry's fault, but it is certainly the merit of Monsieur André Tournouër, to whose untiring energy and generosity the Paris Museum owes the collection in question.

The author divides the Patagonian Ungulates into Rectigrada and Flexigrada, and the latter again into Digitigrada and Plantigrada. *Pyrotherium* and *Astrapotherium* resemble the Proboscidia and Amblypoda by their almost straight and massive limbs; the principal function of the bones of the foot, tightly crowded together, being apparently to afford a solid basis to these articulated pillars. These are the Rectigrada (Rütimeyer's term 'Säulenfüsser,' for the Proboscidia, implied the same meaning).

Ungulates with more flexible limbs, as the result of the display of more activity, either made use of their limbs for locomotion alone, both fore- and hind-limbs touching the ground by means of their third phalanges only (*Theosodon, Diadiaphorus, Proterotherium*), or the fore-limbs were modified for fossorial or prehensile functions (*Nesodon, Colpodon, Homalodontherium*, etc.). When they were thus employed, the weight of the body had to be supported solely by the hind-limbs resting on the whole planta. The former are the Flexigrada digitigrada, the latter the Flexigrada plantigrada.

Anterior limbs.—The anterior limbs of *Pyrotherium* are exceedingly short as compared with their hind-limbs, so that the head must have been inclined towards the ground. *Astrapotherium*, with longer fore-limbs and not provided with a proboscis, was enabled to turn its fore-limbs obliquely outwards, and thus to reach the ground with its mouth after the manner of the giraffe. The anterior limbs of the North American *Dinoceras* present striking resemblances with those of *Astrapotherium*.

[1] Albert Gaudry, "Fossiles de Patagonie. Dentition de quelques Mammifères" (Mém. de la Soc. géol. de France, Paléontologie, t. xii, mém. No. 317, 1904).

The digitigrade *Proterotherium* was more monodactyle even than the horse; the differences with the 'Solipeda' are, however, considerable.

Nesodon, among the Plantigrada, has fore-limbs presenting more analogies with the Carnivora and certain Rodents (e.g. the squirrels) than with the herbivorous Ungulates. The fore-limbs of *Homalodontherium* at first sight recall those of an enormous Carnivore, but like those of *Nesodon* were endowed with less mobility.

Posterior limbs.—The posterior limbs of *Pyrotherium* are, like the anterior, those of a Rectigrade; having to fulfil the same functions as the posterior limbs of the Proboscidia and the Amblypoda, these organs have converged in the three distinct groups. *Astrapotherium* also was apparently a Rectigrade; the body being less massive than in the typical Rectigrada, the posterior limbs were endowed with a certain degree of mobility.

Like the Rectigrada, the Digitigrada touched the ground with their ungual phalanges only; the conformation of their astragalus, however, shows that their posterior limbs possessed a great amount of flexibility. Besides, their limbs were slenderer and more elegant.

In the Plantigrada, on the contrary, the rotation of the tibia on the astragalus was rather limited; their fore-limbs being adapted to prehensile or fossorial functions, they required a certain amount of immobility in their posterior limbs.

III.—Det centrale Norges fjeldbygning. By K. O. Björlykke. 8 and 595 pages and map. With a supplement: Notes on Graptolites from Bratland in Gausdal, Norway. By Charles Lapworth. 16 pages and plate. Norges Geologiske Undersögelse, No. 39. Kristiania, 1905.[1]

THE first part of this memoir of the Geological Survey of Norway deals with the district around the Mjösen Lake. The formation known as Sparagmite is in great force. It lies unconformably on the Archæan, and consists of—

1. At the top, light-coloured felspathic sandstone and conglomerate.
2. A limestone, the Biri-kalk.
3. A conglomerate, the Biri-conglomerate.
4. A dark-coloured sparagmite (felspathic sandstone).

Above the Sparagmite Formation there is a quartz-sandstone and grey-greenish shales, shown by the author to be allied to the blue quartzite of Valdres, and above this come the schists, etc., of the Silurian. The author gives a full account of the Sparagmite Formation, and in his second part traces it into Osterdal, the valley through which the Christiania-Trondhjem railway runs.

The third part of the memoir deals with Gudbrandsdal. The author describes some small patches of rock which underlie the dark

[1] "On the Geology of Central Norge," by K. O. Björlykke. A summary of a larger (the above) work, 2 and 27 pages and map, Kristiania, 1905.

sparagmite, and which he believes to be the oldest part of that formation.

Passing to the tributary valley of the River Jöra, the author deals with a rock, which, though resembling sparagmite, rests upon and not under, the Silurian, and he names it the Younger Sparagmite. He believes it to be of Devonian age. It is closely associated with the post-Silurian eruptive rocks of the Jotunheim Mountains.

The fourth part of the work deals with Valdres, Hemsedal, and Laerdal, and the author traces the Younger Sparagmite to the Sogne Fjord, and south-west into the district around Vossevangen. The rocks included in the Younger Sparagmite Formation are a part of those grouped together by Kjerulf[1] under the general title Höifjelds kvartsen.

Brögger speaks of the group as the Younger Gneiss Formation, and has described it in his valuable memoir on the Hardanger vidda.[2] He points out that in places it bears a great resemblance to the Archæan Gneiss, but, like Kjerulf, he treats the succession as normal, and the Younger Gneiss as of later date than the Silurian schists upon which it rests.

In the present work Mr. Björlykke describes how various authors, himself included, have been led to suggest that some part, at least, of this younger gneiss may be overthrust masses of the Archæan. Professor A. E. Törnebohm has gone much further, and has brought forward a series of overthrusts on a gigantic scale in explanation of the structure of the Scandinavian mountains.

Mr. Björlykke's recent work in the field leads him to think that the theory of overthrusting has been carried much too far, and he doubts whether the evidence goes further than to show quite local pushing of strata over one another. He accordingly reverts to the opinion of Kjerulf and Brögger, that the succession is on the whole normal, and the Younger Gneiss group newer than the Silurian schists. He divides that group into two parts. The first is the Younger Sparagmite Formation, of which we have already spoken, and in the other he places the more gneiss-like rocks, suggesting that they are more or less metamorphosed igneous rocks connected with the great mass of post-Silurian eruptives which are largely developed around the head of the Sogne Fjord and in the Jotunheim Mountains.

The author explains that Norway is affected by two systems of folding. The first, which he terms the "Mountain-chain" system, runs N.N.E. and S.S.W., whilst the other, which he terms the "Strike-system," runs W.N.W. and E.S.E.

The memoir is accompanied by a sketch-map geologically coloured, and numerous maps and photographs are inserted in the text.

In the Supplement, Professor Lapworth describes and figures a series of Graptolites collected by Mr. Björlykke in Gudbrandsdal.

HORACE W. MONCKTON.

[1] Th. Kjerulf, "Udsigt over det sydlige Norges geologi," Christiania, 1879, p. 164.
[2] "Lagfolgen paa Hardanger vidda Norges Geologiske undersögelse," No. 11, 1893.

IV.—United States Geological Survey (Bulletin No. 266, Series C, Systematic Geology and Palæontology). Charles D. Walcott, Director. Palæontology of the Malone Jurassic Formation of Texas. By Francis Whittemore Cragin. With Stratigraphical Notes on Malone Mountain and the surrounding Region near Sierra Blanca, Texas. By T. W. Stanton. pp. 1–109, plates i–xxix. 8vo. Washington, 1905.

IN the introductory portion of this paper Mr. Cragin describes the geology of the region, with remarks on the fossils and related faunas. This is followed by a stratigraphical sketch by T. W. Stanton, accompanied by a map, showing the Sierra Blanca and other mountain chains with their contour-lines. The rest is taken up with a description of the species of fossils.

After describing the topographical features of the region, an account of its geology is given, in which it is stated that all the fossils were obtained from Malone Mountain and the neighbouring hills — the Malone hills. These hills extend, trending at first eastward and then southward as a practically continuous Jurassic outcrop through the Neocene, for a distance of a mile and a half.

The Malone formation was found to be extremely rich in fossils, as the long lists clearly testify. They include a new species of *Astrocœnia* (*A. Maloniana*), two echinoids, *Holectypus* and *Pygurus*, many molluscs, a serpula, and the fin spine of a selachian of an indeterminate genus.

The affinities of its fauna clearly refer the Malone formation to the Jurassic. The sections Undulatæ and Costatæ, to which several of the Malone Trigonias belong, are exclusively Jurassic. With one exception, represented by a single somewhat imperfect mould, none of them agrees perfectly with generic groups hitherto known from Cretaceous rocks exclusively. This evidence of the age of the rocks is further strengthened by that afforded by the Ammonites, the genus of most frequent occurrence being *Perisphinctes*, the species of which show the closest affinities with those of the Tithonian of Europe.

It is observed that a considerable number of the fossils of the Malone formation are identical with some of those of the Alamitos beds, described by Castillo and Aguilera in San Luis Potosi, Mexico, and there can be little doubt that the Malone and Alamitos beds represent approximately the same horizon.

Twenty excellent plates and a serviceable index complete this interesting monograph on Jurassic fossils. A. H. F.

V.—Contributions to the History of American Geology. By George P. Merrill, Head Curator of Geology, U.S. National Museum. From the Report of the United States National Museum for 1904, pp. 189–734, with 37 plates and 141 text-figures. 8vo. Washington, 1906.

THIS record of the birth and growth of geology in the United States and Canada, written by one of the most able and

indefatigable workers, is of exceptional interest. It is indeed a wonderful record. That a geological map of the United States of America (the area referred to at that time being east of the Mississippi) should have been published in 1809, is in itself a remarkable fact, and one of which Americans may justly be proud. That map, showing the areas of Primitive, Transition, Secondary, and Alluvial Rocks, and also tracts of Rock Salt, was the product of William Maclure. It was the earliest attempt at a geological map of America, and was published six years prior to William Smith's map of England and Wales: of course, a far more elaborate work. Geological descriptions, mostly of a mineralogical nature, had been published in America as early as 1785. The author terms the first period of American geology the Maclurean era (1785–1819), the second, the Eatonian era (1820–29), being marked by the labours of Amos Eaton; and onwards the periods are divided according to the State Surveys, the first decade of which dates from 1830 to 1839, and here again the United States was in advance of Britain. From beginning to end the work is full of information on the history and progress of geology; and it is profusely illustrated with portraits of the workers, from those of Benjamin Silliman and William Maclure to E. Billings and C. D. Walcott. Special efforts were made to obtain portraits representing the individual at the period of his career under discussion. In an appendix there are tables showing the gradual development of the geological column, as given in the principal textbooks; and there are also brief biographical sketches of the leading workers in American geology.

REPORTS AND PROCEEDINGS.

Geological Society of London.

I. — May 9th, 1906. — Aubrey Strahan, M.A., F.R.S., Vice-President, in the Chair.

The Chairman read, on behalf of the Council, a letter of condolence addressed by the Foreign Secretary to the Swiss Geological Society on the loss of Professor Eugène Renevier, For. Memb. G.S., whose death was the result of an accident, which took place only a few days before the proposed celebration of his professorial jubilee at Lausanne University.

The Chairman announced that the Council had resolved to award the proceeds of the Daniel Pidgeon Fund for 1906 to Miss Helen Drew, Newnham College, Cambridge, who proposes to examine the relationship of the Caradoc and Llandovery rocks in South Wales, between the Llandeilo and Fishguard districts.

The following communications were read:—

1. "The Eruption of Vesuvius in April, 1906." By Professor Giuseppe de Lorenzo, For. Corr. G.S.

After the great eruption of 1872 Vesuvius lapsed into repose, marked by merely solfataric phenomena, for three years. Strombolian activity followed, varied by lateral outpourings of lava in 1885, 1889, 1891, 1895, etc., and by outbursts from the principal crater in 1900 and 1904. Fissuring of the cone and slight outpourings of lava began in May, 1905, and continued until April 4th, 1906, when the first great outburst from the principal crater occurred, accompanied by the formation of deeper and larger fissures in the southern wall of the cone, from which a great mass of fluid and scoriaceous lava was erupted. After a pause the maximum outburst took place during the night of April 7th and 8th, and blew 3,000 feet into the air scoriæ and lapilli of lava, as well as fragments derived from the wreckage of the cone. The south-westerly wind carried this ash to Ottajano and San Giuseppe, which were buried under 3 feet of it, and even swept it on to the Adriatic and Montenegro. At this time the lava which reached Torre Annunziata was erupted. The decrescent phase began on April 8th, but the collapse of the cone of the principal crater was accompanied by the ejection of steam and dust to a height of from 22,000 to 26,000 feet. On April 9th and 10th the wind was north-easterly, and the dust was carried over Torre del Greco and as far as Spain; but on April 11th the cloud was again impelled northward. The ash in the earlier eruptions was dark in colour, and made of materials derived directly from the usual type of leucotephritic magma; but later it became greyer, and mixed with weathered clastic material from the cone. The great cone had an almost horizontal rim on April 13th, very little higher than Monte Somma, and with a crater which possibly exceeds 1,000 feet in diameter; this cone was almost snow-white from the deposit of sublimates. Many deaths were due to asphyxia, but the collapse of roofs weighted with dust was a source of much danger, as was the case at Pompeii in A.D. 79. The lava-streams surrounded trees, many of which still stood in the hot lava with their leaves and blossoms apparently uninjured. The sea-level during the 7th and 8th of April was lowered 6 inches near Pozzuoli and as much as 12 inches near Portici, and had not returned to its previous level on April 18th. The maximum activity coincided almost exactly with the full moon, and at the time the volcanoes of the Phlegræan Fields and of the Islands remained in their normal condition. The author believes that this eruption of Vesuvius is greater than any of those recorded in history, with two exceptions—those of A.D. 79 and of 1631.

2. "The Ordovician Rocks of Western Caermarthenshire." By David Cledlyn Evans, F.G.S.

The ground dealt with is practically identical with that examined by the late Thomas Roberts, whose notes were published in 1893. It extends from the River Cywyn on the east to the Tave on the west, and from the base of the Old Red Sandstone on the south to the top of the *Dicranograptus* Shales on the north. The area is, in the main, a denuded anticlinal fold with an east-and-west axis,

complicated by minor folds, faulting, thrusting, and crushing. The succession on the northern limb of the anticline is as follows:—

Bala-Caradoc.	
Llandeilo.	*Dicranograptus* Beds. *Asaphus tyrannus* Beds.
Llanvirn.	*Didymograptus Murchisoni* Beds. *Didymograptus bifidus* Beds.
Arenig.	*Tetragraptus* Beds.

The succession on the southern limb is similar, but passes up into higher beds, as shown below:—

Lower Llandovery.	
Bala-Caradoc.	Slade Beds. Redhill Beds. Sholeshook Beds. Robeston Wathen Limestone.
Llandeilo, Llanvirn, and Arenig as above.	

The crushing and fracturing of the rocks have brought together into a small area facies of rocks differing lithologically and in faunas, the difference being well shown in corresponding beds on opposite sides of the anticline. The majority of faults are strike-faults, many of them being thrusts; these are sometimes so close together that the structure cannot be fully displayed on the 1 inch scale. Cleavage affects the rocks on the northern limb, but is almost absent on the south; it was induced at a later date than the faulting. The chief igneous rocks are intrusions of diabase; and there are ashes in the Llanvirn and Llandeilo Beds and an ashy shale in the Arenig.

A description of the entire succession of rocks is given, accompanied by lists of fossils, and each division of importance is followed through its whole extent as shown in the area. In correlating the rocks, it is shown that the Middle and Upper Arenig rocks compare with those of St. Davids; the Llanvirn rocks are very similar, lithologically, to the beds of Llanvirn and Abereiddy, and the faunas are practically identical; the Llandeilo rocks are in the main like those of Pembrokeshire, but the *Leptograptus* division of the *Dicranograptus* Beds closely resembles the Rorrington Flags of Shropshire; the Bala-Caradoc rocks fall into the divisions already established by Marr & Roberts in an adjoining area; and the rocks assigned to the Lower Llandovery are barren of organic remains, as they are elsewhere.

II.—May 23rd, 1906.—R. S. Herries, M.A., Vice-President, in the Chair. The following communications were read:—

1. "On the importance of *Halimeda* as a Reef-forming Organism; with a description of the *Halimeda* Limestones of the New Hebrides." By Frederick Chapman, A.L.S., F.R.M.S., and Douglas Mawson, B.E., B.Sc. (Communicated by Prof. T. W. Edgeworth David, B.A., F.R.S., F.G.S.)

Calcareous algæ, nullipores, *Lithothamnion*, etc., have been frequently referred to as forming important contributions to the rock

of coral reefs. The material obtained in the great boring, the lagoon borings, and lagoon dredging at Funafuti has yielded a considerable quantity of *Halimeda*; and Dr. Guppy has described a *Halimeda* Limestone in the Solomon Islands. Evidence such as this shows that the important deposits of calcareous plant-remains forming at the present day can scarcely be paralleled by any deposit formed in past geological times, except, possibly, the limestones of the Alpine Trias, which owe their origin to the thallophytes *Diplopora* and *Gyroporella*. Among other *Halimeda* Limestones mentioned by the authors are those of Christmas Island, Fiji and Tonga, and the New Hebrides. The examples from the last-named group are described in detail. They differ considerably one from the other in the condition of preservation of their chief organic contents. Chemical and microscopic analyses of the several examples are given. *Halimeda* seems to be more liable to decay than *Lithothamnion*, corals, or foraminifera, and yet it appears to retain its structure to a considerable depth in reefs. Much of the fine powdery limestone associated with coral reefs, and more especially with upraised coral islands, may be primarily due to lagoon and other deposits formed by the agency of *Halimeda*.

2. "Notes on the genera *Omospira*, *Lophospira*, and *Turritoma*; with descriptions of New Species." By Miss Jane Donald. (Communicated by Professor E. J. Garwood, M.A., Sec. G.S.)

In a previous paper the author referred to the researches of Ulrich and Koken among the earlier Gasteropoda, and to the groups into which they had divided them. Much knowledge is still required with regard to their origin and relationships before really satisfactory divisions can be made. The new species described in the paper belong to three genera, characterised by the possession of a band on all the whorls formed by the gradual filling up during growth of a sinus, and not a slit, in the outer lip. The genera *Lophospira*, Whitfield, and *Turritoma*, Ulrich, are not really true Murchisonidæ, but are allowed for the present to remain in that family. Ulrich places *Omospira* in the family Raphistomidæ, but it is not a characteristic member, for the whorls are more convex and the spire higher than is the case with the other genera belonging to the family. Ulrich's description is quoted and discussed, and one new species is described from beds of Upper Bala age. Of the genus *Lophospira*, Ulrich's four sections, and sub-sections of certain of these, are discussed. Five new species are referred to the *perangulata* section, one new species and one variety to the *bicincta* section, and one species to the *robusta* section. One new species is described of *Turritoma*. The specimens dealt with are mainly from the collections of Mrs. Gray, the Sedgwick Museum, the Bristol Museum, and the Geological Survey of Scotland.

The Rev. H. H. Winwood, in exhibiting a series of water-colour drawings of Mexican scenery, said that these beautiful sketches were executed by Miss A. C. Breton, during a recent visit to Mexico; and, as the International Geological Congress was about to meet in that country, she thought that some of the Fellows might like to see

them. They represented that line of active and extinct volcanos which stretches from the Gulf of Mexico on the east to the Pacific Ocean on the west, including Orizaba, Popocatepetl, Jurullo, and Colima. A short extract from the publications of the Mexican Geological Survey, translated by Miss Breton, was read respecting the formation of Popocatepetl ('smoking mountain'), showing how the successive periods of volcanic energy may be marked (*a*) by a period of lava-flow, (*b*) by one of breccia, and finally (*c*) by one of ashes. The angles of slope of the volcanos were drawn to scale.

Professor H. J. Johnston-Lavis exhibited upward of forty lantern-slide views to illustrate the late eruption of Vesuvius and its effects. Nearly all these were taken by the exhibitor, who explained the different phenomena portrayed. He considered this eruption to resemble mostly that of 1822, although the present crater was larger, attaining 1500 feet both north-by-south and east-by-west; it was probably 500 to 600 feet deep at least. The remarkable character about this eruption was the large amount of fragmentary material ejected, especially in a north-easterly direction, crushing in the roofs of the buildings in the towns of Ottajano, San Giuseppe, and Terzigno. At the first-named locality the depth attained was about 0·75 metre, made up as follows:—

m.	
0·04	Grey dust.
0·49	Reddish lapilli, chiefly 'supplementary ejecta.'
0·20	Black vesicular scoria, chiefly the 'essential ejecta.'

The material which fell at the Observatory and Naples had much the same arrangement, but was of course less, and practically only sand and dust. Near the base of the cone the ejecta attain to blocks several tons in weight; and it may be estimated that, at the north-eastern toe of the great cone, in some places the débris must be 60 feet thick. It is to be seen as much as 30 feet in thickness in the new ravines that have been formed.

After careful study, the speaker had come to the conclusion that the remarkably uniform and deep scoring of the cone by very regular 'barrancos' was due to the sliding and avalanche-like effect of the rapidly accumulating fragmentary material on the steep slopes, and not due to water action.

The mountain seems to have opened at four, if not five, different places on the south-western, southern, and south-eastern sides, giving rise to at least three important streams of lava. Another rift, to the north-north-east of the cone, emitted lava that forms an apron on that side of the mountain, and must of course have been formed early in the eruption, that is, before the 7th to 8th of April.

The ejected blocks are chiefly old lavas and scoria, partly re-cooked and metamorphosed, with their cavities filled by tachylytic juice from the fluid magma of the neighbouring chimney. The cavities are also often lined by sublimations of augite, hornblende, leucite, microsomite, hæmatite, halite, and a well-crystallized yellow deliquescent mineral, which proves to be a new chloride of manganese and potash, for which a new mineral name is proposed. A few

fragments of limestone, and the various mineral aggregates derived by metamorphism from it, are met with, but they are chiefly re-ejected old ejected blocks. A light-green spongy tachylite is also frequent.

The 'essential ejecta,' either as scoria or lava, do not show any marked difference from the usual products of Vesuvius in such eruptions during the last three centuries.

Although much damage has been done, great areas of rugged lava surfaces that would have required centuries to render cultivable, are now available for the growth of woods, vines, and herbaceous plants.

III.—June 13th, 1906.—Sir Archibald Geikie, D.C.L., Sc.D., Sec. R.S., President, in the Chair. The following communications were read:—

1. "Recumbent Folds produced as a Result of Flow." By Professor William Johnson Sollas, Sc.D., LL.D., F.R.S., F.G.S.

Professor Lugeon, in his treatise on the pre-Alps of Chablais, has described a series of recumbent folds so greatly exceeding in horizontal extension their vertical thickness, that they are commonly spoken of as sheets rather than folds; they lie with remarkable flatness one on the other, and, as a rule, those higher in the series extend farther to the front than those below, a feature referred to as 'déferlement.' The roots of several of the lower of these folds are visible in the high Alps adjacent, but the roots of the higher folds, which form the pre-Alps, must be sought in the zone of Mont Blanc and the Briançonnais. Thus some of the uppermost folds may have surmounted the obstacle presented by Mont Blanc, on their way to the front in the pre-Alps. Many of the features presented by recumbent folds are more suggestive of flowing than bending. Experiments have been made with pitch-glaciers (poissiers) in which an obstruction had been placed. In this way folds were produced, one of which was not unlike the Morcles fold behind the Diablerets, another was like the Pilatus, and yet another like the Sentis, and the fourth compared with the overslide of the Bavarian front; all four exhibit déferlement. In this experiment the lower limb of each fold is adjacent to the similar limb of its neighbours; but in another experiment, in which two obstacles were used, the results were nearer to those seen in the mountains where the lower limb of a superior fold reposes on the upper limb of the fold immediately beneath it. Movement of this character may possibly explain the want of continuity of certain beds at the conclusion of the movement.

2. "The Crag of Iceland—an Intercalation in the Basalt Formation." By Dr. Helgi Pjetursson. (Communicated by Professor W. W. Watts, M.A., M.Sc., F.R.S., Sec. G.S.)

The existence of fossiliferous deposits on the west coast of Tjörnes, Northern Iceland, has been known for nearly 160 years. Mörch enumerates 61 species of mollusca, and concludes that the temperature

must at that period have been much milder than at present. Gwyn Jeffreys and Searles Wood, from the shells, considered that the deposit could not be younger than Middle Red Crag, but Mr. Starkie Gardner was inclined to assign a greater age to it. Dr. Thoroddsen thinks that these Crags are younger than the 'Old Basalts' of Tjörnes. The author finds, however, that, at a height of 500 feet above the sea, they are overlain by the 'Eastern Basalts,' and are indurated and altered by them. Thus there is a fossiliferous intercalation, over 500 feet thick, occupying part of the great gap between the Tertiary and the Pleistocene rocks, the latter containing indurated ground-moraines. The basal layer of the Pleistocene Series is fossiliferous, and has yielded 22 species of mollusca, 20 of which represent a highly Arctic fauna (with *Yoldia arctica*), such as is at the present day found living along the coasts of Spitzbergen. Certain of the larger basalt dykes are cut off at the base of the Crag. The absence of the Crag deposits from other localities is explained by the erosion of the coastline.

CORRESPONDENCE.

THE ZONE OF *OSTREA LUNATA*.

Sir,—I have no objection to the distinction which Mr. Brydone wishes to make between 'international' and 'provincial' zones, but I must maintain my opposition to his conception of a provincial zone.

I believe that I express the generally accepted view of such a zone in briefly defining it as a band of strata characterised by a special group of species. That is the definition of a zone given by me in vol. i, p. 34, of the Memoir on the Cretaceous Rocks of Britain, and the zone of *Ostrea lunata* as proposed in vol. iii of that memoir is based upon that definition, the name being an index of the fauna and not of the zonal limits.

Now Mr. Brydone wants to restrict a provincial zone to a band in which some type-fossil can always be found in every foot of its thickness! Moreover, he has the boldness to say that all the zones introduced by Barrois in the South of England below that of *Marsupites cor-anguinum* answer to the test he imposes. I am greatly surprised that he should commit himself to such a statement, for it is not true even of the Chalk of Dover, while he ought to know that in Dorset *Holaster subglobosus* is so rare in the upper part of the Lower Chalk that I have not heard of one being found. Again, in some parts of Wiltshire *Terebratulina lata* is quite a rare fossil in the *Terebratulina* zone. These are cases in which the Chalk is almost unfossiliferous, and how can his idea of a zone be applied to them?

He asks me how I would define the upper and lower boundaries of the zone of *O. lunata*. I reply, in precisely the same manner as the other zones adopted in my memoir are defined, not necessarily by the index-species, but by means of the fauna as a whole. It may be that its base is best defined by the incoming of *T. gracilis*, and